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EDITORIAL

A Look Back and a Glance Ahead

IN November 1924 the Washington Section of the Society of American Foresters met to hear an address by W. B. Greeley, then Chief of the Forest Service on The Importance of Forest Research. During the course of this address Mr. Greeley urged action to stimulate and correlate forest research in the United States. As a result of this suggestion a committee headed by Dr. E. H. Clapp was appointed to prepare a report on a national program of forest research. This report was published by the American Tree Association and served as the basis for the McSweeney-McNary Forest Research Act, the tenth anniversary of which is being commemorated by this issue of the JOURNAL.

A ten-year period is too short a time adequately to measure the significant accomplishments of any research program. It is not unlikely that during the first ten years of the Royal Society that Robert Boyle, John Evelyn, and the other original Fellows may have had some misgivings concerning the accomplishments and probable future of what was to become the greatest of all scientific societies. It is not unlikely either that during the past ten years those most directly concerned with the inauguration and development of a national program of forest research also may have had some misgivings concerning the accomplishments and future of that program. Be this as it may, one thing is certain: The passage of the McSweeney-McNary Forest Research Act is second in importance and significance only to the Act of March 3, 1891 authorizing the President to set aside forest reserves from the public domain.

During the ten years since the McSweeney-McNary Forest Research Act was enacted regional forest or forest and range experiment stations have been established in all the important forest regions of the continental United States; a research personnel sufficiently well trained and experienced to meet the immediate needs has been developed; a partial inventory of the forest resources of the Nation has been made; direction and guidance has been given to many forest and forest utilization practices; many social and economic aspects of forestry have been determined; and fallacious and fictitious forest practices and concepts have been discarded. In short, the scientific basis of American forestry has emerged largely during the past ten years. The articles in this issue of the JOURNAL are a brief but impressive record of the accomplishments of the Branch of Research of the Forest Service, a record of which any public agency may well be proud.

But what about the future? Is the present organization and support adequate to

meet the forest research problems of the future?

Prognostications of future developments are always hazardous. In so far as forest research is concerned, however, certain trends now appear to be discernible, indistinctly to be sure. Furthermore, it is not unlikely that the developments in forest research will follow somewhat the same pattern as research developments in the older sciences.

Many of the research problems undertaken by the regional forest experiment stations have been of a survey nature. To complete them efficiently required a large number of workers, effective organization, and sound administration. The success of the regional forest experiment stations in completing projects of this nature is indicative of their organizing and administrative skill.

Nevertheless, over organization and excessive administration are genuine dangers to a research agency. Some administration is of course essential, but the major objective of research administration should be to expedite the work of competent scholars. In the last analysis, the discovery of new knowledge and the advancement of learning is largely an individual matter. Research flourishes in an atmosphere of freedom. It is stifled by unwarranted restrictions, by undue regulations, by over administration. It withers under the influence of excessive and undue pressures from within or without. Research of the highest order can only be done by a group of thoroughly competent zealous scholars working without thought of gain to themselves, approaching their problems in a spirit of selflessness and of detachment, in an atmosphere of intellectual freedom.

The training of a corps of scientific workers and research administrators willing and able to do their best work under such conditions is the greatest present day challenge to the forestry schools of America; their acquisition and assimilation by the forest experiment stations the greatest challenge to the Branch of Research.

The Branch of Research is not the only agency in the United States engaged in forest research. Many of the forestry schools; various departments of many universities; the botanical gardens; and other research institutions are engaged in researches having direct or indirect forestry implications. More often than not the research programs of such agencies deal more directly with so-called "fundamental" problems. Nevertheless, these fundamental researches often have far reaching implications. The problem of closer cooperation and coordination between the regional forest experiment stations and other publicly and privately supported research agencies, and, indeed, with the administrative branch of the Forest Service itself unfortunately still awaits satisfactory solution. This problem is a difficult one, but the advantages to be gained by its solution are so obvious that decisive action should not be long deferred.

The purpose of calling attention to these future problems is not to detract from the past achievements of the Branch of Research. All foresters within and without the Service have a deep feeling of satisfaction over the achievements of the Branch of Research since the passage of the McSweeney-McNary Act. In a brief span of ten years the Forest Service has developed an effective and efficient forest research organization, an organization which has served the public well, an organization which has met its problems with ability, an organization which is destined to serve the American public in a still wider field of usefulness. Foresters the country over take justifiable pride in the achievements of the Branch of Research. They congratulate it on its past record and wish it still greater success in the future.

THE SPONSORS OF THE McSWEENEY-McNARY ACT COMMEMORATE ITS TENTH ANNIVERSARY

FORESTRY has long been a major interest with me. This is natural, because of the important place that the forests hold in the economic and social structure of my home state. Oregon leads all the states of the Union in area of forest land and in volume of standing timber. For the past 15 years her lumber production has been exceeded only by that of Washington. Obviously, the prosperity of the state depends and will continue to depend on her forests and forest industries. The same is true, through possibly in less degree, of many other states. The perpetuation of these forests and forest industries is a matter of vital concern, whether he realizes it or not, to every citizen of the forest states and to every citizen of the United States.

The function of forest research is to find out the underlying principles and the methods by which our forests can most effectively be protected, managed, and utilized, so that they will yield the maximum benefits to society in the long run. It is a constant source of gratification to me that I have been privileged to have a part in legislation which is doing much to put forest research, and hence forestry practice, on its feet in the United States.

CHARLES L. McNARY,
United States Senator (Oregon).

IN THE past, one of the advantages of living on a farm was the feeling of security—the assurance that almost anyone of ordinary intelligence and able and willing to work could make a reasonably adequate, even though modest, living. This advantage no longer exists. We have distressed rural areas as well as areas of industrial distress. Much of this rural distress may be traced to destructive exploitation of the forest resources and the consequent shut-down of industries dependent on them.

One of our biggest problems today is how to enable rural people to earn a better and more dependable living. To do this, it is not enough merely to sustain and improve, in proper balance, the productivity of crop and pasture land. We must keep the forest land also at work in producing raw materials for industrial and home use and in creating a wholesome environment for rural living. East of the Plains farm woodlands comprise one-third of the farms, and also one-third of the forest area. In the West the proportions are smaller. The products of the farm woodland, and employment on it and on other forest land, add materially to the farmer's income, but they could and should add much more.

Research has been responsible for much of the progress of American agriculture. It can in like degree increase the direct and indirect income from woodlands on farms and elsewhere, and promote the less tangible benefits of forests in creating better living conditions. It is because I believe this that I welcomed the opportunity to sponsor the Forest Act of 1928.

JOHN McSWEENEY,
Congressman at Large (Ohio).

THE DECENNIAL OF THE McSWEENEY-McNARY ACT

By EARLE H. CLAPP[1]

THE McSweeney-McNary Forest Research Act celebrated its tenth birthday on May 22, 1938.

The passage of this Act was the second landmark in the recognition and development of forest research in the Forest Service. The first was the creation of the Branch of Research, which brought together in 1915, in one strictly research organization unit, research activities which prior to that time had been scattered among several administrative units.

Forest research did not, therefore, begin in either the Forest Service or in the Department of Agriculture with this Act. It had been under way for two or three decades in varying amounts, mostly small, with varying recognition and support, mostly uncertain. Ample legislative authority existed for the work that was under way.

The question was often asked at the time the legislation was under consideration, and it is still in point, why was new legislation needed? For some lines of work—and important lines—legislative authority was either lacking or insufficient. Other enabling legislation was more or less fragmentary and scattered, so that there was a genuine need for supplementing and rounding out legislative authority and bringing it all together under one Act. This need was probably greater in the Forest Service than in any other bureau in the Department of Agriculture having responsibility for forest research.

But the greatest need for the legislation arose from an entirely different cause. It grew out of a rapidly spreading public appreciation of the importance of forestry in our social and economic structure and of a rapidly growing public demand that much more be done about it; but there was an appalling lack of appreciation of what good research could and should contribute to a national forest program. The major justification of the Act was, therefore, to inform and arouse public opinion and to focus both public and Congressional attention on an unappreciated and badly neglected forest activity. It was also to give both Congress and the Budget a general guide for evaluating the forest research needs of the country.

The Washington Section of the Society of American Foresters recognized the situation and appointed a special committee which submitted its recommendations in the form of a report entitled "A National Program of Forest Research." This report was published by the American Tree Association under the auspices of the national Society and its recommendations later formed the basis for the McSweeney-McNary Act.

The Act did five main things:

It authorized forest research of broad scope.

It specified the main field structures or organizations at which the work should be centered.

It authorized an initial 10-year financial program containing maximum limits for appropriations set high enough to raise the sights very materially over those which had previously existed, and also a long-time financial program without maximum limits.

It focused public and Congressional attention on forest research far beyond anything which had previously been known.

In a real sense Congress by passing the Act endorsed and accepted for its own the program on which the legislation was based.

What the Act has meant, what it has

[1]Associate Chief, U. S. Forest Service, Washington, D. C.

accomplished in its first 10 years, is shown in some detail in the articles which follow. Here only a few brief references must suffice, and in making them it is fully recognized that the progress and results of research in the Forest Service during the past decade can be credited to the McSweeney-McNary Act only in part. Many other factors have contributed, not the least among them the invaluable pioneer work of the early years which developed techniques, created a nucleus of personnel, and established ideals. Research by the forest schools, other state institutions, and private institutions have made contributions also which have helped to further the work of the federal agencies.

Of first importance, the Act made possible the real beginning of research in forest economics. That already started on forest taxation under the provisions of the Clarke-McNary Act was the exception which proved the rule. It thereby recognized the tendency of the biological and physical sciences to outdistance the economic sciences, and attempted to keep the latter abreast of the former. It recognized that American forestry would necessarily be a lame and halting effort if it lacked the necessary understanding of the powerful economic forces which so largely dominate our national life.

Most comprehensive among the economic projects so far undertaken and still far from complete is a nation-wide survey of the forest resources of the United States as a basis in part for the sharper and sounder formulation of problems, objectives, and solutions, and for sounder national, regional, and state policy-making and planning.

Of specific accomplishments in research itself only a few can be mentioned in passing:

Gratifying initial progress in the science underlying fire control and suppression, and the opening of new vistas for future attacks.

Marked progress in techniques for investigating forest and range influences. And in addition a good start in building up the factual basis on the relationship between forest and other vegetative cover and run-off and streamflow and erosion, so that it is no longer necessary to depend on observations alone. The pronounced influence of the forest shown by this work has been one of the factors leading to the revolutionary provisions of the recent flood control legislation which recognizes the management of land along with engineering works in flood control and stream regulation.

Revolutionary changes in forest mensuration and, growing out of this, in the application of mathematics to the laying out of many other kinds of research and the final analysis of the data. This application of mathematics has brought an assurance of correctness in both techniques and results far beyond anything previously known.

Greatly accelerated progress in a better scientific foundation for the silviculture of many forest types. This means the gradual removal of one series of handicaps to the growing of timber crops.

Similar acceleration in the foundation for the management of many range types.

Marked improvements in the techniques for naval stores extraction.

Forward steps in the fundamental chemistry of wood and its constituents which may later prove to be of great significance.

A material improvement of the older pulping processes and the development of new processes, with the incidental increase in the number of species which can be used for pulp and paper. Both are important steps toward putting the United States in the position to become self-sufficient in pulp and paper requirements whenever it becomes desirable or necessary.

What holds promise of being revolutionary steps in the use of wood in low-

cost housing and other structures. This is a service to the part of the consuming public which needs it most.

Contributions large enough to have made possible two over-all national surveys of the forest and the range problems respectively, the results of which were incorporated in the so-called Copeland Forest Report and the Norris Range Report. Both represent, in their respective fields, the most ambitious projects yet attempted from the standpoint of scope and intensity of coverage, formulation of problems, and scope and character of the remedial action recommended.

On the side of organization and facilities, the act has helped to crystallize a regional experiment station organization, highly decentralized from the standpoint of Washington office supervision, as contrasted with state or purely local stations, a revolutionary change in the organization of federal research.

As a phase of this regional station organization, it has helped to crystallize the basic concept of centering in each station all of the problems of a region of similar conditions—silvicultural, range, watershed, economic, etc.—and thereby of insuring a maximum of local supervision and correlation where it can be done most effectively.

This regional organization, with a total of 12 stations, now covers the entire United States.

It has helped to crystallize such other organization questions as the following: Having the scientific staff of each station work out from a central headquarters to all parts of the region as needed; wherever possible, maintaining the headquarters in cooperation with a university in order to obtain the stimulus and other benefits of the university atmosphere; for efficiency in research as well as for the highest values for demonstration purposes, concentrating the field work as fully as possible in a series of carefully selected experimental forests and ranges, each representative of local conditions. The number of such experimental forests and ranges now exceeds 90, in contrast with perhaps 15 of ten years ago.

It is primarily because of the impetus given to research by the Act and to the flexibility of this decentralized organization that it has been possible to take advantage of the unemployment relief program to build up plant facilities at experimental forests and ranges to an extent undreamed of 10 years ago. Many of these forests and ranges now have good laboratories and comfortable living quarters; and the forests have an intensive utilization road system, etc., which permits highly intensive research and management.

The Act has helped to maintain the plan of one national forest products laboratory to serve the needs of the entire country, and thus to insure the greatest volume of work and the fullest possible coordination at the lowest cost.

The vision of future needs and possibilities in the Act was responsible in part at least for the new and greatly enlarged laboratory facilities for forest products research made possible at Madison, Wisc., under legislation approved April 15, 1930.

The provisions of the Act for regional forest experiment stations and a national forest products laboratory have helped to emphasize the responsibility of the federal government for a substantial contribution to the solution of national and regional or interstate problems and those of federally owned lands, and conversely to emphasize the responsibility of the states and other agencies for state and purely local problems.

Regional forest experiment stations and a national forest products laboratory have afforded the organization vehicle for favorable cooperative relations with other bureaus of the Department charged with responsibility for forest research. Investigators stationed at these institutions ca

work most effectively with Forest Service personnel and at the same time maintain suitable relationship with their own bureaus.

The Act and the various things that have grown out of it have helped drive home the concept that the forest of any area is a biological entity, all the elements of which are integrated with all the others and are influenced by them. The biological elements of the forest of an area or region extend in the same way into the social and economic field. All of this exceedingly complex interrelationship has emphasized the need for conducting research on the basis of these relationships, or in brief, the need for cooperation by groups of specialists in coordinated, well-rounded-out, many-sided attacks in contrast with isolated and purely individual work.

The demand for men growing out of the provisions of the Act has helped materially to insure the promise of a satisfactory career in any one of several phases of forest research, to encourage forest schools and other universities to provide the facilities for training, and to encourage investigators themselves to spend the time and effort and money needed to train adequately for the work. Incidentally, the Act has helped to place increased emphasis on the need for highly qualified men both as to inherent mental qualifications and to advanced training if real progress in investigative work on difficult problems is to be made. In 1928 the availability of competent, well-trained men was the primary limiting factor in the development of forest research. This is no longer true.

In addition to the beginning of work in the economic field already referred to, the Act has meant the gradual strengthening of the financial support for every other class of research authorized for which the Forest Service is responsible, that in forest products being much the smallest proportionally.

But the picture has its shadows as well as its high-lights. Many of the things contemplated at the time of the passage of the Act have not been realized.

The establishment of forest experiment stations in Alaska, Hawaii, and the West Indies is still in the future.

Although reasonable progress has been made, the first 10-year financial program is still far from having been realized owing, in part perhaps, to the long and severe depression and the submergence of the regular at the expense of emergency federal activities. Deficiencies in the regular financial program have, however, for most classes of work, been more than offset by allotments from emergency funds. But the latter have been available primarily for building up plant facilities rather than for research activities *per se*.

In some respects the Act has been shown to be faulty or inadequate.

Sufficiently explicit provision was not made for investigations in the crucially important field of forest and range influences, and consequently this work has suffered in comparison with other lines of research.

The financial limitations placed on the forest survey have proved a serious handicap, and no provision was made for greatly needed authority to keep resource and other data current after the completion of the initial survey.

A station was not authorized for the important Plains Region, and an amendment to the Act has been necessary to provide for it.

No provision was made for the publication of investigative results currently as obtained, and consequently much-needed information must frequently follow the already overburdened processes of formal publication and a delay of several years.

Specific provision was not made for forest land and forest resource planning, although provision for the collection of much of the basic data needed in such

planning presumably carries with it the authority to make the most effective use of the data.

The fact that the ultimate objective of all forest resource conservation is human welfare was not sufficiently recognized—either in the form of the Act itself or in the subsequent research under it. To crystallize a realization of the great need for such research and the equally great possibilities that it offers has taken several years of severe depression, which has brought into open and acute form social conditions and problems long smoldering and often heretofore obscure, and has required in addition the emphasis and policies and program of a socially minded national administration.

The future possibilities of forest research and what the McSweeney-McNary Act, in its present or in amended form, may contribute to them are not within the scope of this article. But it should be said here that forest research, if utilized, affords the greatest assurance of doing the right things in forest conservation, in the right way, at the right time. The present-day United States, with all of its critical resource problems and its increasingly complex and crucial social and economic difficulties, cannot afford to neglect such a means.

The need for research in a balanced national program is greater than ever before, and consequently the opportunity is greater. Whether the need is met and the opportunity is taken full advantage of depends in large measure upon the men responsible for forest research in the Forest Service and in the Department of Agriculture.

An article, "A New Day in the Naval Stores Industry," originally scheduled for this issue of the Journal, has been omitted because of lack of space. It will appear in a later issue.

THE MARCH OF SILVICULTURE

By THORNTON T. MUNGER[1] AND LEONARD I. BARRETT[2]

WHEN men remove products from the forest as they remove coal from a mine—assuming that with the removal of each ton the end of their profitable enterprise is so much the nearer—the process is exploitation. When they remove products from the forest as they harvest a crop of hay—taking care that the same rich earth will have every opportunity to yield as abundant a crop in the due course of years—the process is silviculture. Axe and saw are the essential tools used in both processes. The chief difference between the two processes is the technical skill based on scientific fact that is prerequisite to all silvicultural advance.

For its first two decades or so, American silviculture rested on a very slender foundation of scientific fact. The few and youthful foresters, schooled largely in Old World textbooks, tried ingeniously to adapt European practices to the multitudinous variety of timberlands that they encountered over these broad United States. The need was obviously for research to reveal the best methods for regenerating, bringing to maturity, and harvesting the country's 862 tree species, appearing in an almost infinite number of combinations in uncounted forest types.

A small group started from scratch. They made silvical studies for the individual tree species. And they established permanent sample plots, or selected areas where trees and their surroundings were described in detail at the time of establishment of the plots, and again at intervals thereafter. These plots were generally established in the conditions created by the empirical studies. So when the McSweeney-McNary Forest Research Act was passed in 1928, the path for real progress in silviculture had at least been blazed and slashed out. In recounting the rapid march of silviculture in the last decade, recognition must be given to the pioneering scientific work carried on since the earliest days of the Forest Service.

The notable progress in silviculture in the last decade is largely due to the more ample funds which have been appropriated. But there are other contributing causes. An increasing number of research foresters, trained by post-graduate study and seasoned by experience, have become available. Also, these well-schooled foresters have greatly improved the tools of their trade, abandoning the crude home-made or ill-adapted instruments of an earlier day for perfected and elaborate recording instruments and handy "gadgets," often forester-designed. Silviculturists have also been apt students in the new school of statistical methods, and have learned how to design their experiments, to do random sampling, and to test statistically the reliability of their data.

New techniques by the score have been developed, further to implement research. The instrumental method has replaced the observational method. Not only have the facts of tree behavior been learned, as for example the very high mortality of newly-germinated seedlings in a cut-over area, but the reasons therefor—excessive temperatures of the ground surface, or disease, or hungry rodents. The great progress in measuring physical factors, both through studies in the field and more fundamental studies in the laboratory, has lifted silvicultural research above pure empiricism. The fatal short-coming of empirical knowledge is its limited application; what has been learned by empirical

[1]Pacific Northwest Forest and Range Experiment Station.
[2]Appalachian Forest Experiment Station.

methods in one forest or stand may not apply at all in another, and the only way to find out is to try it. Truly fundamental knowledge, on the other hand, separates and evaluates all of the factors which have contributed to a given effect, and from it principles may be formulated.

The times have had a stimulating effect on research. Opportunity has knocked loudly at the forester's door. The N.I.R.A. legislation provided temporary opportunity for application of silviculture on private lands, and stimulated rapid assembly of all silvical knowledge from which to write rules of forest practice. That this could be done so well and so quickly in many parts of the United States is a tribute to the progress that silvical knowledge had made.

When a host of C.C.C. boys and other relief workers reported to the forest ready to do planting, stand improvement, and whatever good forest management dictated, it was again a challenge to assemble for practical application the fruits of past studies. Thus research was further accelerated, for what was not known was more conspicuous than what was known. Indeed, in many important forest types lack of silvicultural knowledge became painfully clear as a result of C.C.C. activities.

Some of the silvicultural research from the earliest days has been done at a few field centers on the national forests, which became in time the first federal experimental forests. Today there are over 90 experimental forests and ranges, at most of which research in silviculture is the principal activity. Some are, significantly, on state forests. The multiplication in the number of experimental forests was accompanied by a transformation in the character of the work. It was concentrated; it was stabilized; it became better integrated with applied practices; it furnished demonstrations which could be easily seen.

The literature of forestry has grown fast in the past decade, and half of the titles are in the field of silviculture. The completion of the series of bulletins entitled *Timber Growing and Logging Practice* in each of the major commercial forest regions is a major achievement. These bulletins point out in nontechnical terms such modifications of ordinary logging practices as are necessary to lift the process out of the category of exploitation and into that of silviculture. Recent bulletins of the experiment stations are more scholarly, and more evidently based on sound scientific data, than those of the previous decades.

The progress of silviculture in the East, which possesses a wide variety of both valuable and inferior species, has been stimulated during the past decade by some enhancement of forest values. This enhancement has been brought about in part by industry's recognition of the utility of species formerly considered of little value, and in part by its acceptance of raw materials of smaller sizes, poorer quality, or lighter stands per acre. Not only have additional species found a market, but there has been a marked tendency toward the manufacture of specialized products from all usable species. A more important development affecting the economics of timber growing, however, has been the unparalleled expansion of roads and highways. Suddenly, because of improved transportation facilities, limits of merchantability have been lowered and new possibilities for woods operations realized.

Expansion of industrial use to include trees of little previous value are exemplified in Lake States jack pine, and the second-growth pines of the South. Ten or fifteen years ago on millions of acres jack pine was considered little better than a necessary evil, a mere transition from utterly worthless scrub species to the magnificent white and red pines of the original forest. The picture has changed so rapidly that today silvicultural measures are practiced for the perpetuation of jack pine.

Millions of acres of second-growth southern pines occupied a somewhat similar status. Until recently it was generally believed that at least another generation must elapse before such areas would again be ready for the sawmill, and somewhat less time before they could be "worked" for naval stores. Within a period of five years, however, this young timber has become the basis for a $200,000,000 expansion of the wood-pulp industry. The danger now is that cut-throat competition between the sawmill, pulp mill, and turpentine mill, and the small landowner's desire for immediate cash returns, will encourage reckless exploitation. The industries have available a background of research and experience in southern pine silviculture and economics that can insure the future productivity of the forest land, and a highly profitable integration of the industries themselves.

In some eastern hardwood regions, particularly where virgin stands remain or where there is a substantial element of old growth mixed with a younger generation of trees, experimental cuttings have demonstrated that various modifications of the selection system often provide the maximum increment of high-value products. Hence different forms of partial cutting are well established in the management of these commonly uneven-aged types.

Most eastern forests are, however, even-aged, as a result of close utilization and clear cutting of the preceding stand. Where utilization has not been so close, "wolf trees"—generally low-quality "hold-overs" from previous stands—present a serious problem. Standards for liberation cuttings, cleanings, thinnings, and other improvement measures have been developed for some of the more valuable types and species. Although these standards have been adopted for use in rehabilitating some large areas of public lands, and a small area of privately-owned timber lands, there are still many types where trained foresters have lacked the knowledge to use effectively the emergency labor that in late years has been placed at their disposal in undreamed-of volume. The rehabilitation of vast forest areas of even lower productivity, wrecked not only by heavy cutting but also by periodic fires, comprises another of the largest and most difficult silvicultural problems in the East.

In the West, where the timber is predominantly virgin, the bulk of the silvical research has been directed to determining best methods of cutting and reproducing naturally the major forest types. There has been little time as yet for silvicultural research on the secondary species or the minor types.

In the Southwest and the Intermountain region, ponderosa pine, although almost wholly in public ownership and therefore subject to rather complete regulation of cutting methods, presents grave silvicultural problems because of the relatively unfavorable physical environment. Low and uncertain rainfall results in scanty seedling establishment; and this, coupled with the current use of nearly the whole forest area for range livestock production, renders precarious the life of young seedlings. Long-continued study has, however, evolved methods of cutting, of slash disposal, and of integrated range management far more successful than earlier procedures.

In California, a mixed type in which perpetuation of sugar pine is desired has been the locus for an immense amount of basic silvical study and empirical experimentation. Any modification of present logging methods in an extremely mountainous country is expensive, and Nature herself imposes obstacles to man's efforts by tending to eliminate by overhead shade the light-demanding sugar pine. Successful fire protection also favors the inferior species. In very recent years, also, the redwood type has had much-needed attention, particularly with respect to the

practicability and desirability of applying selective logging.

In the Pacific Northwest the silvics of Douglas fir has been well studied—seed production, seed dissemination, seed storage, seedling establishment, seed-tree survival, and the role of fire. As a result, practices on public lands have been materially modified.

In the northern Rocky Mountains foresters have been baffled for years by the problem of perpetuating the very valuable white pine in stands which when harvested contain an equal volume or more of practically worthless species. The very intensive recent research, the climax of that begun 30 years ago, has so illumined this subject that foresters now know this type, the silvics of its species, the role of stored seed in natural regeneration, and the place for clear cutting and for selectivity. But they, like their colleagues in other regions, are still searching for means to overcome the great obstacles of economics, fire, insects, and disease, in putting into practice the ideal silviculture.

One of the significant developments since 1928 is the integration of silviculture with other phases of forestry. Silviculture is no longer considered an end in itself, and American foresters are more and more realizing that the best silviculture, in the long run, is that which pays the best in general welfare, to paraphrase Dr. Schenck. Silvicultural research and economic research are now beginning to join hands.

In reviewing the march of silvicultural research, there appear certain trends in its course. The limelight of forest interest has latterly been thrown on subjects other than silvics—soil and water conservation, economics, range management, wildlife management, recreation, aesthetics, social relations—somewhat to the overshadowing of interest in silviculture. Is the basic business of foresters—growing trees—being neglected thereby?

The availability of relief labor has made possible stand improvement measures that were formerly considered to be impractical of application for many years to come. This has greatly stimulated latent studies at most of the experiment stations in pruning, thinning, cleaning, and other forms of stand improvement. Growth of knowledge in this field should make a long forward march in the next decade.

The improvement in mobile logging machinery, such as tractors and trucks, has made feasible a degree of selectivity in cutting that was not possible before. Silviculturists have hitherto been circumscribed by the exigencies of logging with animals, donkey engines, and railroads. Now a revolution in logging methods has opened a new field, and research men in silviculture are turning their attention to devising good silvicultural practices that will take advantage of, or at least be compatible with, selective logging.

Though silvicultural research has made great progress in the past decade—and with never more than two-thirds of the authorization granted by the Forest Research Act—it still has a long way to go. The silvics of scores of important trees and types have not yet been thoroughly studied. Methods of regeneration and of tending the crops must be worked out which consider not only quantity production but also quality of product. As the transition is made from virgin to tended forests, a silviculture must be devised that will safeguard against fire, insects, and disease, and that will provide for multiple-use forest management; timber growing must be correlated with wildlife management, with recreation, grazing, and water conservation. With the constantly changing economic and social demands upon the forest, research must move rapidly forward to meet or anticipate changes. Silvicultural research should always be in the van, but it must give such leadership that woods practice will not lag far behind.

SCIENCE IN FIRE CONTROL[1]

WITHOUT including esthetic, recreational, stream control, and similar so-called intangible values, recent statistics give our annual forest fire loss as about $10,000,000. The reduction in area burned has in some regions been impressive; in the "piney woods" of the South, for example, where prior to 1920 the per cent of annual burn was quite commonly 150—"all of it burned over once and a half of it twice"—the per cent is now less than 5 over wide areas.

In general, this appreciable progress has been made by doing the many things which now seem obvious but which in the early days were far from that. American forestry inherited from Europe no science or technology of fire control. Administrative men had to accomplish with inadequate resources the tremendous job of providing shelters, roads, trails, and communications for a far-flung control organization.

These things were done, for the most part, without benefit of any formalized research. It was not until 1916, in fact, that a specific proposal was made to apply research methods to fire as a forest phenomenon in the United States, and not until 1926 that the research possibilities were comprehensively stated. The passage of the McSweeney-McNary Forest Research Act in 1928 greatly stimulated fire research and authorized the appropriations necessary to a more adequate attack on an extremely complex and difficult problem. Research under this act is now proceeding in the fields of behavior of fire, effects of fire, and the mechanics of fire control.

Research in fire behavior includes studies of forest fuels, fuel moisture, ignition, and measurement of fire danger. Fires obviously cannot burn without fuel. In a country as broad as the United States there are enormous differences in forest fuels. A basic job of research has been to classify them, at first on a purely silvical basis, more recently on a basis of certain characteristics indicative of both rate of spread of fire and its resistance to control. This work has now been refined to a point where already in at least one fuel type in one region the rate of spread of a fire may be calculated from a mathematical formula.

From the beginning it was recognized that fuel moisture is a major control in combustion. The meteorological elements which affect it are insolation, temperature, humidity, and precipitation. Research at several western experiment stations has largely overcome early impediments to the measurement of these factors and their integrated effect on fuels. Instruments devised in these studies include low-cost rain gauges, low-cost wind gauges, and the fan psychrometer. The duff hygrometer and the extremely simple but no less useful wood cylinder now measure what previously was only crudely estimated—the fuel moisture itself. Having determined what effect meteorological elements, singly or more often in combination, have on fuel moisture, the investigators have gone on to predict the changes in the fuel which will result from measured changes in the weather. One phase of research which many think is of great promise is the effect of density of the forest canopy upon the fuels beneath it. Methods of timber-stand improvement and particularly of final cutting will in the future be evaluated not simply for their silvicultural effects but also for their effect on fire conditions.

No matter how dry the fuel, it will not burn unless ignited. In most forest regions the spark which kindles forest fires is applied by man. Either by carelessness

[1]Material for this article was contributed by various workers in fire research and assembled in its present form by R. D. Forbes of the Allegheny Forest Experiment Station.

or intent, men are still responsible for a shocking proportion of our forest fires. A late development in forest-fire research —undertaken by the Southern National Forest Region—is the employment of a trained psychologist to study the motives which lead men to set fires deliberately and the psychological characteristics which contribute to their setting fires carelessly. Here is a wide opportunity for fire prevention. Lightning rather than man is responsible, however, for the majority of fires in some of the most heavily timbered regions of the United States. Here lightning storms have been studied by the Weather Bureau and the forest experiment stations, with resultant increased accuracy of forecasts. Lookouts have also been trained to identify storms as soon as they come within view, as dangerous or harmless.

Fire danger is compounded of dry fuels and abundant sources of fire. Accurate measurement of this danger therefore is necessary to put the work of fire protection on a business basis. In the northern Rocky Mountain region, where fire has wrought more havoc and caused more ghastly tragedies before being brought under control than in any other timbered region of the United States, the major factors of fire danger were first integrated into a numerical scale on an instrument known as a fire danger meter. Fire danger meters suited to local conditions have since been produced by investigators in several other parts of the country, both east and west. The fire danger meter, based on the various factors which previous research had shown to contribute importantly to forest danger, has given the forester nearly everywhere a standard and consistent terminology in place of his former characterization of fire conditions as "easy, pretty bad, bad, and damned bad." The research in measurement of fire danger has made possible the reasonably accurate determination of average danger which existed during a specified period, such as an entire fire season. It has begun to furnish the long-needed basis, when costs and losses are balanced against the character of the fire season, for evaluating differences in fire danger between years, and thereby for rating efficiency of fire control. Eventually it will furnish the basis for determining differences in fire danger between localities and regions.

Investigations of the effects of fire, or fire damage, in all parts of the country have revealed many useful facts. For example, it has been definitely demonstrated that the obscure and indirect forms of damage are even greater than feared. The mere wounding of trees by fire not only depreciates butt-log values, and in the special case of trees being chipped for naval stores reduces both the amount and quality of the product; it also increases susceptibility to attack by insects and fungi, which often results in high eventual mortality. Country-wide standards of evaluating all forms of forest fire damage are urgently needed as a basis for determining justifiable efforts and expense in fire protection.

The American people long since learned that fire is a bad master. The possibility remains that the forester can make of fire a good servant. In several parts of the country he early recognized the value of fire in slash disposal under certain circumstances, which subsequent pathological and silvicultural research have now more accurately defined; and in reducing other special hazards. Only recently fire has been investigated as an aid in the treatment of additional forest ills. In the South, controlled burning in certain pine types has been found to aid the production of favorable seed-bed conditions, the utilization of native forage plants by game and domestic animals, and the reduction of some forms of tree disease. Experiments elsewhere have indicated that fire may sometimes be effectively used to reduce fire hazard and as a silvicultural

measure. However, even where the benefits have been demonstrated to outweigh the damages, the conclusion is inescapable that fire must be under control not only as to area but often as to heat intensity. Research has no mean task before it in providing the basis for and helping develop such fire technique.

In few fields is the demand more insistent than in that of the development of the mechanics of fire control, that research be "practical"; and the bulk of the work done under the McSweeney-McNary Act has been eminently practical. Today a man is selected for fire lookout duty only after specially devised eye-tests have demonstrated his fitness; on the job he is immeasurably aided by newly devised or adapted equipment—visible-area maps, visibility meters, smoke-penetrating binoculars, and special eye-glasses, to mention but a few. A greatly improved railroad engine spark arrester of the "cyclone" type has been developed. In the Cabinet National Forest it has reduced railroad fires of all kinds from an average of one per two trains in 1931 to about one per eight trains in 1936 and 1937. All except yard engines on this division of this railroad are now equipped with such arresters. Studies of fire breaks, to prevent the unimpeded spread of fire and to constitute a battle front from which fire fighters may work, have in several forest regions determined the principles of topographic location, width and depth of cleared line, and the use of highly-developed and extraordinarily efficient machinery for fire break construction. Prior to these studies much useless and unnecessary construction was done by rule-of-thumb, or by methods dictated by personal preference.

Fire control planning has been greatly refined by research. Penetrating analysis of long-term fire records has evolved certain principles which determine "hour control," or the speed with which fires must be attacked. Engineers have contributed notably to the transportation phase of this problem. Later studies have covered strength as well as speed of attack, and for the first time have suited size of organization, or treatment, to the current forest condition as diagnosed by fire-danger measurements. They have revolutionized in many respects and have universally improved former procedures for determining how many detection men, fire chasers, and suppression crews should be provided for any particular forest property and where they should be stationed. For example, efficiency of "coverage" was improved by 20 per cent in one region without increasing man-power. Possibilities of saving large sums of money by using a smaller organization with safety during definitely easy seasons were also disclosed.

In the period covered by the operation of the McSweeney-McNary Forest Research Act, the social-economic objectives of forestry have been greatly amplified. Although the forest-crop function has been relatively minimized, the requirements of adequate fire control for all forest lands have been considerably expanded. The broadened concepts of forest-land management constitute a new basis for raising fire-control standards. Intensified effort by investigators into every phase of fire control is demanded. Better machinery and such special devices as portable two-way radios developed by administrators are all playing their part. Special emphasis is justified in such of the newer fields as the use of chemicals and airplanes. Fully as important is the re-examination by forest managers of every plan and every measure of fire protection in the light of the new information now available.

CREATING NEW FORESTS

By C. G. BATES and PAUL O. RUDOLF[1]

THE creative work of forest planting is a fundamental if not a paramount part of forestry. Because of its obvious objective it is better understood by the public than other aspects of technical forestry, but it is by no means so simple as it appears. The planting of a few trees is no problem, but the growing and planting of small trees by the millions, as an activity of mass production, requires much study and careful development of technique.

Within the past decade America has increased its rate of forest planting 20 times. In 1929 forest trees were planted on about 18,000 acres of land—about the average for many preceding years. In 1936, largely because the C.C.C. boys and other emergency workers were on the job, the current annual planting was increased to 400,000 acres. Research in forest planting under the McSweeney-McNary Act has endeavored to break trail for this extraordinary development.

Most fundamental of all items in reforestation is the source of seed used. Long-lived plants must be thoroughly adapted to the climate of the site where they are planted. Research at the Northern Rocky Mountain Station on ponderosa pine has furnished striking proof of this. Plantings of seed from all over the West developed normally for about 12 years, although there was much variation in size of the planted seedlings. Then came a warm winter "chinook," followed by an extreme drop in temperature such as occurs only rarely, even in the Northern Rockies. Certain of the "foreigners" among the ponderosa pine seedlings were eliminated as by a pogrom, and the survivors, among them the local strains, told an interesting tale of unsuspected climatic zones within the broad region from which they had come.

Green ash is a tree distributed along streams through most of the Plains region. It has been demonstrated by laboratory tests and nursery developments that only the northerly forms of the species survive well in the extreme cold of a North Dakota winter; also that these same forms are most drought resistant. For the Plains, it has been concluded that seed should not be used in final plantings more than one or two degrees of latitude from its source; broadly speaking, seed collecting for any specific project should be done within a maximum radius of 100 or 200 miles.

Studies at the Southern and Intermountain Forest Experiment Stations have developed simple tests of cone and seed maturity. These consist of floating sample cones in liquids of known specific gravity, to guard against picking cones which contain unripe seeds and are difficult to open. Very careful technique is needed to insure that seed, once collected, is properly ripened, that it does not mould or ferment before it can be warehoused, and that processes used in the "extracting," cleaning or drying do not destroy its viability.

Research has shown that seed lots of certain species of trees must be given "after-ripening" or pregermination treatments if, after storage they are to be usable by the following spring. Still other lots must be provided safe storage in order to be available for use should the crop of successive years be a failure. Thorough-going studies by the Southern Forest Experiment Station of seed of long

[1]Lake States Forest Experiment Station.

leaf pine, a crop difficult to extract, preserve, and germinate readily, revealed the need for low moisture content at beginning of storage and low temperature throughout.

The highly perishable nature of the seed of at least half-a-dozen important conifers, both eastern and western, as well as of some eastern hardwoods, has posed a vexatious problem which recent research has solved with the discovery that such seed may be preserved quite safely in cold storage at 32 to 40° F.

For the relatively few kinds of seed which fail to germinate promptly if kept dry in cold storage and held for spring sowing, cold moist storage, or "stratification" (usually in sand) has been shown to be almost unfailingly successful. Fall sowing in seed beds is a fair substitute, although often producing new problems of protection against mice and other enemies. The problem of seeds having very impervious coats has been solved by the use of acid treatments in many cases; in others, by scarification.

Improvement in nursery culture has resulted from the many recent studies of sowing-density, shading, root-pruning, watering, soil management, and disease and insect control. In planting areas where recent drought losses have been severe, development of stock for special site conditions, by carefully controlled watering and the selection of sites best suited to the species actually available for planting, is important, and has been the subject of research. Over a period of years studies of forest types and of site factors have helped to define the limits of temperature, moisture, light, soil texture and acidity, within which natural reproduction of a given species will occur, and by inference the conditions under which the same species might safely be planted.

Research has supplied not one, but several answers to very practical questions. Should sites on the Michigan sand plains be planted with red pine 2-0 seedlings, as has been the custom? On one with better-then-average soil (a former white pine site), planting of 2-0 red pine stock will be successful in most seasons, but the seedlings may have to be released from brush competition to continue good growth. Slightly poorer sands, covered now in part by scrub oak and jack pine, require larger and sturdier stock to meet the competition for moisture and to outgrow competing vegetation. Very poor sands with very little cover except grass, often representing serious soil deterioration by fire, are more difficult to plant because of the high temperatures and low water-holding capacity of the soil. One such site has produced fairly good red pine, but jack pine or Scotch pine is perhaps a better risk for a first crop to cover and build up the soil.

There is an intriguing possibility that planting sites may be classified and identified by means of plant indicators. Often these are shrubby or herbaceous survivors of no commercial value, left when their associates—the commercially-valuable trees—were removed by man. If conditions since logging continued to permit them to flourish, it is fairly good evidence that the tree species may be restored to the same site by planting; if they too have disappeared, it is probable that the sites will no longer support the original forest type. Although plant indicators have not yet been adequately studied in any forest region of the United States, a start has been made in the Northeast and in the Lake States.

In many of our forest regions, areas that once supported valuable forest stands have become covered with brush following logging and fires. In such cases the shade above ground and roots below ground constitute a very serious obstacle to planting. Elimination of the brush by hand is very expensive. In northern Minnesota a brief trial of heavy machinery, the "Olympic" and "Killifer"

plows, has given promise that such work can be done satisfactorily by such means at reasonable cost. In California a modification of the bulldozer, known as the "Plumas stripper," has been used successfully to prepare brushy sites for planting where topography is not too rough, at a cost of $5 per acre.

One of the most fruitful and practical fields of forest-planting research has been the effect of different classes of planting stock on survival. The superiority of sturdy, well-balanced planting stock has been proved time and again in the Northeast, the Lake States, the South, the Intermountain Region, and California. A striking illustration is the experimental planting made on the sand plains of lower Michigan in the fall of 1935. At the end of the severely dry, hot season of 1936, survival percentages were as follows: 1-0 stock, 5; 2-0 stock, 14; 1-1 stock, 18; 2-1 stock, 38; and 2-2 stock, 59. An important exception to the usual relations, however, has been determined through nursery studies in the Pacific Northwest. Two-year seedlings of Douglas fir grown at a density of 75 trees per square foot and root-pruned can be safely substituted for 1-1 stock, at a considerable saving in cost.

That within any given class of planting stock the larger individuals consistently do better than those which are smaller and less developed, has been notably demonstrated with the southern pines, red pine, and some 14 hardwood species used in the Prairie-Plains region. First-year survival of the best grades of these hardwoods averaged 60 to 70 per cent higher than that of the poorest grades.

Every novice raises the very natural question: "Why not sow forest tree seeds on the ground where the trees are to grow permanently?" Unquestionably direct seeding has at least one theoretical advantage over planting. A planted tree starts its career with a curtailed, unnatural root system, and can never entirely overcome the handicap. There is always danger that in fast, low-cost planting such roots as the tree possesses will be doubled up. Such "kinks" in the roots never disappear unless that particular root-section dies and is replaced. Most, but not all, of the experimental evidence is to the effect that natural seedlings have better root systems than planted seedlings. Direct seeding, on the other hand, has rarely if ever proved as cheap as planting of nursery stock, because the percentage of failures is large. In good seed years nature overcomes this handicap by the extravagant dispersal of seed.

Natural seeding appears to be successful most often on tracts from which animals have been driven out by fire, but in which a favorable seed bed has been created. Experimentation emphasizes more and more that the destruction of seed outweighs hazardous physical conditions as a factor causing failure of direct seeding. It is therefore quite possible that the invention of a thoroughly cheap, durable, and portable screen to protect seed spots might turn the tide in favor of much more direct seeding, under selected conditions, than now appears feasible. If this means trees of longer life and greater vigor, the practice deserves every encouragement. Adequate investigation of direct seeding involves longer periods than are ordinarily associated with problems of artificial forestation. There is therefore no time to lose in beginning them.

A brief article cannot even mention the thousand and one different ways in which recent research has contributed to the many techniques involved in seed-collecting, nursery-growing, and out-planting of more than one hundred different tree species used extensively in American forest planting. Only the more fundamental advances in the reforestation program have been touched upon here. As in most forest research, such advances, important as they are, are but reassuring evidence of greater achievements yet to be wrought by research in future decades.

NEW CONCEPTS IN FOREST MENSURATION

By F. X. SCHUMACHER[1]

IN 1925, Donald Bruce[2] wrote, "American forestry has, until recently, failed most notably in two respects. First, instead of being a profession it has been a crusade. Second, it has not been a true science. It is impossible to analyze the progress of mensuration during the past quarter century without vividly appreciating the latter of these two failures."

Bruce went on to paint a somewhat gloomy picture of accomplishments in forest mensuration, not at all in a spirit of pessimism but rather to emphasize the fact—obvious to very few foresters at the time—that the application of scientific method to forest mensuration had been completely neglected.

Up to a decade ago, a volume or taper table, a yield or other growth table, depended upon one or more free-hand curves through zones of plotted points, their courses sometimes contingent upon the investigator's preconceived notion of what they should be; sometimes following plotted points with a faithfulness which overlooked entirely the possibility that the sample points might be defective in certain respects, or insufficiently representative of the populations from which they were drawn.

The growth of thought upon problems presented by the forest, which followed the establishment of the regional forest experiment stations, has brought realization that forestry is not in itself a science but is rather a meeting ground of sciences. In particular, forest mensuration has blended physical and biological sciences, and has expressed them through mathematical analysis. The mensurationist has become imbued with the steady conviction that inductive reasoning from observational data, involving as it always does elements of uncertainty, deserves better than rough and approximate discussion. He has sought and found in modern mathematical statistics improvement in computational technique. This, in turn, led to a most important step: the contemplation of defects in observational procedure—defects often so serious that nothing beyond rough and approximate discussion was warranted. He learned that in other branches of scientific endeavor, particularly in biology and agriculture, the practical requirements of research had, through the work notably of R. A. Fisher and his associates, moulded mathematical structures to befit observational programs consistent with their requirements. Finally he learned to devise observational programs in forestry investigations suited to unambiguous mathematical analysis and to exact tests of hypotheses.

The new concept of the timber cruise is a practical case in point. If the timber volume of a forest property—large or small—is to be sampled in such a way that the probable discrepancy between the estimated and the true but unknown volume be assessed without ambiguity, the evenly spaced, rigid pattern of cruise strips or sample plots upon which foresters have been brought up must be wholly abandoned. The mathematical requirements for the solution of the problem imply that the constituent parts upon which "sampling error" is based be located independently and at random; the part that forest mensuration plays is to devise an observational program that will at once reconcile the practical limita-

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[1]Duke University. In Charge, Section of Forest Measurements, U. S. Forest Service, 1930-1937.
[2]Bruce, D. Forest mensuration today. Jour. For. 23: 281-286. 1925.

tion of time and funds with the free play of pure chance location of sample strips or plots, upon which the estimate is to be based. The key to the problem lies in a method of sampling the forest with a precision known roughly in advance—here the cruiser's experience plays its part—and accurately determinable from the sample data.

All this presupposes not only unambiguous definition of what is considered to be the true volume, but also the ability to make measurements and other observations—such as species and type—consistent with it. Should, for instance, systematic error in measuring tree diameters creep into the work, the discrepancy between the estimate of volume and true volume cannot be made to approach zero in an otherwise efficient job, but the discrepancy will approach, instead, the effect of the systematic error. Foresters have, in general, carefully guarded against systematic errors of measurement and the possibility of personal bias.

On the other hand, a common systematic error of estimate rather than of measurement in the timber cruise, and one not universally recognized, is that of volume tables. The difference between the actual volume of a tree and its estimate as given by the volume table, is made up of two components: (1) a part due to variation in volume among trees of the same size in the *same stand;* and (2) a part due to variation in volume among trees of the same size in *different stands.* While site and density may account for much of the latter source of discrepancy, residual average differences between stands in excess of 5 per cent occur in one-third of the stands of certain species. Regardless, therefore, of however strong is the basis in number of trees which a volume table rests upon, the use of that table in calculating the volume of a given stand results in an error of estimate which is subject to the variation between stands.

This type of error becomes important when the discrepancy between estimated volume and corresponding true volume is to be—with moral certainty—within about 10 per cent. Its correction, if practicable, lies in the use of volume tables based upon tree data of the timber to be cruised; if not practicable, it is hardly worth while to hope for such accuracy. The same line of argument applies to estimates of cull and breakage losses when the true volume is, by definition, the net or sound volume.

Strangely enough, these concepts of the difficulties attendant upon so every-day a job of the practicing forester have followed upon, rather than led up to, a more urgent class of problems of forestry research: problems of field and laboratory experimentation and the testing of hypotheses appropriate thereto.

Within the narrower confines of forest mensuration, serious consideration of questions involving tests of hypotheses has contributed notably to the resources of the mensurationist in dealing with issues peculiar to volume, growth, and yield investigations. For example, the test as to whether the volume of a forest might be estimated satisfactorily through the medium of one or more volume tables based upon the data of another forest was, until recently, considered an important preliminary to the cruise. The examination of test sample tree volumes led to logarithmic expressions of volume in terms of tree size; thence to the kernel of the test, the determination of the size range within which a volume table based upon data of one locality, or tree class, might be used in another. But its very solution involved abandoning the test as trivial when it was discovered that a number of test trees of the order of 15-30 is sufficient for local volume table purposes, and the labor of making the new table is no greater than that of an adequate test of the suitability of a table already at hand.

An outgrowth of yield investigations, particularly with reference to the needs of the nation-wide forest survey, is the conviction that yield tables need not be confined to normally-stocked stands; for considerable advance has been made in the introduction of stocking as a variable along with age and site class. A normal yield table becomes, in consequence, merely a special case of the general yield table. Furthermore, investigations of the effect of degree of stocking upon yields are so promising that it is fully to be expected that general yield tables of the future will include methods of testing the rate of change of stocking with advancing age of stand.

Of much broader implication, however, is the fact that mathematical statistics has widened the horizon of forest mensuration far beyond that which encompasses questions of timber measurement, as these were understood in the past. It not only has supplied the scientific method to investigations of volume, growth, and yield, but it has carried concepts developed in mensuration over into other branches of forestry, such as management, influences, economics, products, soils, and the range. Perhaps the most important outcome—and assuredly the most fruitful—is that it has emphasized the need for, and supplied methods capable of yielding, valid tests of hypotheses. Accordingly, it is largely replacing the unreplicated field and laboratory experimentation of the past—inherently incapable of yielding valid tests of hypotheses—with experimental methods of logical structure, from which may be sorted out the various classes of information the experiment is *designed* to test, by the arithmetical arrangement known as the analysis of variance.

This is not all. Scientific forestry is really coming into its own because the specialist in each of the divisions of forest research is learning to design experiments in his own field so as to maximize the amount of information to be derived from experimentation, consistent with cost and value. In this respect the present decade is, indeed, witnessing wholesome and rational growth.

MANAGING OUR RANGE RESOURCES

By W. R. CHAPLINE and R. S. CAMPBELL[1]

UTILIZATION of range forage offered a perplexing problem to those rough and ready rangers who took over the National Forest Reserves in 1905. The number of livestock on the range was near its peak, and the new Forest Service had immediately to deal with a fully established range grazing industry. It was necessary to allocate range not only between warring cattlemen and sheepmen, but also between jangling individuals and outfits; and to impose grazing fees for forage which before had been as free to all comers as the air they breathed. Range use had to be regulated, forage restored, "sore spots" healed, and watersheds protected.

The urgent necessity for reducing numbers of livestock to grazing capacity compelled the Forest Service to help the owners to develop methods of bolstering profits by increasing productivity of range and livestock through improved management—greater feed production, fewer but

[1]Division of Range Research, U. S. Forest Service, Washington, D. C.

better animals, reduced losses, higher calf and lamb crops, and better condition of animals.

Early empirical studies developed numerous basic management practices, including: (1) adjusting the different classes of livestock to range areas particularly adapted to each class; (2) determining the approximate grazing capacities of the mountain range types, which in turn have shown the number of livestock which may graze on each range; (3) establishing suitable seasons for grazing the different elevational zones, particularly with respect to readiness of plants for grazing; (4) obtaining more even and more effective use of the available forage and preventing damage to the range by better distribution and handling of livestock and avoidance of trampling and localized overgrazing, through such methods as improved water distribution, better salting methods for cattle, and open quiet herding of sheep and goats and bedding them down in a new place each night.

The general application of such improved practices has brought millions of dollars of savings and increased revenues to the livestock industry and has been a big factor in the improved conditions now found on national forests as compared with the average of other range ownerships. Restoration of deteriorated ranges has been materially aided by deferred and rotation grazing which permits full use of the forage but, on a different portion of the range each year, delays grazing until after seed dissemination.

The development of survey methods and the basic management principles to be considered under different range conditions has made possible an inventory of over 50 million acres of national forest range and the preparation of intensive management plans for the use of these lands.

An example from central Utah will illustrate the character of adjustments which studies and plans have made possible. Cattle permitted to graze on a mountain watershed were turned on the foothill range in April and soon drifted to higher elevations. Excessive concentration on the highly productive mountain meadows and the accessible moderate slopes of the elevated plateaus resulted in serious depletion, while large quantities of forage on steep slopes remained unused. Years before, sheep had been eliminated from the range in the belief that they were more damaging to range watersheds than cattle. By taking advantage of economic conditions more favorable to sheep, an exchange was made whereby the number of cattle grazing the range was reduced to what the more accessible areas would support, and in lieu of the cattle reduction the stockmen were permitted to graze the slopes with the number of sheep which could satisfactorily utilize that feed. Cattle were held off the lower range several weeks later in the spring, a fence installed half way up the mountain prevented them from drifting onto the higher elevations before the feed was ready, and a rider distributed salt evenly over the parts of the range to be used by the cattle and helped to control their movements. The sheep also grazed for a shorter season. Damage to the range was greatly lessened, a more effective use of all the feed was obtained, and parts of the depleted range have increased severalfold in grazing capacity in the ensuing years. The more effective use of the range forage has been reflected in a more productive condition of animals that has brought stability to the ranching community dependent upon the national forest range for summer grazing.

Harmonizing grazing—on the 83 million acres of national forests used by domestic livestock—with timber production, watershed protection, wildlife conservation, recreation, and other uses and services of the national forests has required both intensive and empirical studies. Early studies of grazing in relation to timber production, for example, brought out the danger of damage to timber r

production from too heavy or unseasonable grazing and indicated the need for certain major adjustments. More recent investigations in the Southwest are making possible the use of the range without undue injury to ponderosa pine production. Curiously enough it was found that availability to drinking water was a controlling factor. Where water was scarce and cattle drank only once in three days, damage to reproduction was far greater than where water was available at all times; evidently the animals endeavored to satisfy their thirst by browsing the succulent new pine shoots. The answer proved to be more and better distributed watering places and intensive management of the livestock in accordance with the growth characteristics of the forage plants and pine reproduction and the seasonal values of the forage.

The range problem is much more extensive and more complicated outside than inside the national forests, which comprise only 12 per cent of the 728 million acres of range land in the West. Approximately one-fifth the "outside" range is in grazing districts or the unreserved public domain, chiefly in the more arid portions; one-half is in private ownership, primarily in the more productive types; and the remainder is mainly Indian lands, mostly in reservations, and widely scattered state and county lands. As a result of only 50 years of use, combined with the recurrent severe droughts characteristic of this region, the western range as a whole has lost more than half of its grazing capacity. Indiscriminate use of the range as "inexhaustible"—as the virgin forests have ever appeared to pioneer lumbermen—was at the bottom of most of this deterioration. Oversettlement and the breaking up of the range into thousands of units too small for economic operation and the mad rush for farm lands, throwing into cultivation millions of acres too dry for any permanent use but grazing, helped to upset further the balance between range and farm feeds, and between summer, spring, fall, and winter ranges. Thus was built up a large number of complex problems of range restoration, complicated operation, and social and economic rehabilitation.

Departmental responsibility for range research outside the national forests was transferred from the Bureau of Plant Industry to the Forest Service in 1915. Under the aegis of the McSweeney-McNary Forest Research Act, much of the recent expansion of range research has been on untimbered public and on private ranges, until today investigations are under way by the six western forest and range experiment stations to help solve the problems on these ranges as well as on the national forests.

Investigations under way for more than 20 years at the Jornada and Santa Rita Experimental Ranges, of range management in relation to the severe periodic droughts on the semi-arid untimbered ranges of the Southwest, have attracted much attention. These experimental ranges show marked contrasts with heavily stocked unregulated range of potentially equal productivity; the grazing capacity on the managed range is double that of the unregulated, net calf production is more than half again larger, and death losses are only one-fifth to one-third. A profit of 8.8 per cent has been earned on an investment of $69.23 per cow over the last 11 years in an experimental herd on the Santa Rita Experimental Range. To maintain profitable production on these ranges, where forage production may vary several hundred per cent between good and bad years, assurance of adequate range feed in most years is essential. This necessitates stocking about 20 to 25 per cent below average forage production and requires other adjustments in the driest years, as well as delayed restocking. These investigations, now confirmed by studies in other parts of the western United States, show that the density of vegetation reflects the growth conditions of the previous year. Thus, the stand of forage plants may be only one-fourth as much in the

year following drought as in the year of drought. Stocking and management must be adjusted accordingly.

In studies of grazing capacity in the short grass type of the northern Great Plains, in cooperation with the Bureau of Animal Industry, as little as 25 per cent overgrazing in the average year gave lower calf crops, smaller calves at birth, and an average of 72 pounds less weight at weaning than from cows on conservatively grazed range. Feed costs were half again as great on the overgrazed range.

Fundamental ecological and physiological studies, backed by actual grazing tests, have revealed that each major range type has its own peculiar management requirements, which depend upon the nature and adaptability to grazing of its forage cover, and the growth conditions to which the cover is subjected. In addition to climate and numerous biotic factors, soil texture, structure, and fertility play an important part in forage production, the rate of improvement of the native forage stand, and the ability to reseed areas artificially. Studies in several parts of the West have shown that with each stage of depletion of the range vegetation, the situation on a range area becomes more critical as regards both production of forage and restoration of the plant cover. The intensification in the micro-climate is reflected in such features as higher temperatures, more rapid runoff, less absorption of moisture by the soil, greater evaporation, increased requirement of water for the production of an equal quantity of forage, and more damage from prolonged dry spells.

Critical studies of carbohydrate production and storage by several range grasses in relation to growth prove that accumulation of food in the crowns and roots of the plants takes place during the decline of the current leaf and stem growth; that plants draw heavily on stored food in winter and spring before growth of grasses can be observed; that start of above-ground growth depends on food stored the previous summer; and that yield of forage is in direct relation to food production during the current summer. These studies have shown how intensity and frequency of grazing influence the start of growth, food production, forage yield, and winter survival of plants; and how too frequent or too heavy grazing at any time literally starves the plants to death.

The end product of proper range management is, of course, human welfare. Western agriculture is a great complex of interdependent crop farming and range grazing, valued at nearly 12.9 billion dollars. This whole enterprise, involving the welfare of thousands of local communities and even metropolitan centers, reflects adversity or prosperity on the range. All too frequently the strain of improper management has resulted in reduced livestock production, increased costs, overinvestment, tax delinquency, bankruptcy, deserted homes and schools, and blighted hopes. These difficulties may be escaped and communities dependent on the range resource stabilized and maintained only where improved range management is applied.

Much of the progress in sound range resource management has been made during the past decade. In another decade many additional studies should culminate and their results pass into practice. Much information now available only in rough form will be refined. Studies should be extended to many important range areas not previously investigated—among them the unwisely plowed foothill ranges, now abandoned for cultivation, the piñon-juniper areas, and the expansive sagebrush of the West; the woodland ranges of the Ozarks; and the vast southern pineries. These offer opportunities for range livestock production that can be fully realized only with the advance in knowledge which may best be accomplished with the help of research.

REVEGETATING MAN-MADE DESERTS

By GEORGE STEWART[1]

WITHIN the 300,000 acres of land, practically denuded of its original vegetation, which was recently added to the Boise National Forest in Idaho, is a 300-acre "oasis" bearing millions upon millions of perennial grass plants, only a few months beyond the seedling stage. Both the desert and the oasis are man-made.

In earlier years, an excessive number of domestic livestock running on this intensively-used range gradually stripped it of its original vegetation, until today almost the entire plant cover, outside of scattered brush patches and strand-like stream bottoms, is a thin stand of the nearly inedible herb, Gayophytum. Large tracts bear no grass at all, not even the aggressive downy chess. In contrast, within the stout fence of the oasis, are strips of crested wheatgrass, spiked wheatgrass, and smooth brome grass, in various mixtures; the seeded strips 4 feet in width follow the contours of the slopes. Between the strips are 8- to 20-foot intervals of ungrassed soil which will gradually reseed to a full cover—a demonstration of proper seed selection and suitable artificial reseeding methods.

The unfenced portion of this Idaho range is a typical example of about 18 million acres of wild land in the western range country which has so deteriorated under excessive grazing that much of it will require 50 years or more to rehabilitate naturally. Recent investigations under provisions of the McSweeney-McNary Act are now showing how parts of this area can with success be reseeded artificially. This research has been made possible none too soon, since nearly all of these deteriorated ranges are on important watersheds or furnish inadequate range feed during the vitally important winter or spring periods.

Early studies indicated that areas having favorable soil and moisture conditions, such as depleted mountain meadows, could be reseeded with a number of cultivated forage plants and a few native species. That steep and eroded slopes can also be immensely improved by artificial reseeding has more recently been proved on fully 400 acres of previously denuded spots in the Davis County watershed of northern Utah, on which a few years ago disastrous floods originated, and which now bear nearly everywhere a waist-high stand of perennial grass, well-sodded and erosion resistant.

The principal range-reseeding problem now centers on the semi-arid or arid foothills and plains—vast stretches which are either producing little vegetation or have been extensively invaded by unpalatable species. In the Intermountain and Northern Rocky Mountain regions, and in arid parts of the Pacific Northwest, better forage plants have been nearly displaced by the aggressive, short-season downy chess. In the Great Valley of California, owing to too-heavy grazing combined with the long, dry, and extremely hot summers, the original perennial plants have been replaced by Mediterranean annuals. Because these introduced annuals soon dry up and are then extremely low in protein content, planting of more valuable plants is almost mandatory if the range is to be restored.

In addition to the 18 million acres of depleted range land is approximately 23 million acres of range land once cultivated, which is now abandoned to dust

[1]Intermountain Forest and Range Experiment Station.

storms or grown up to Russian-thistle, downy chess, and other short-lived weeds. The combined area of these two classes of land requiring reseeding is greater than that of the state of Iowa.

Because most range land in the western United States has a value of less than $5 an acre, and often only $1 to $3, low-cost methods of revegetation are essential. Yet these must include some means of getting the seed into the ground. Research has helped in this phase also. Again, the use of many native species is now limited by a lack of seed supply. Experiments show that small mountain nurseries can produce seed of mountain brome and slender wheatgrass, two valuable native species, at the low cost of 4 to 8 cents a pound.

Plowing has been found to be prohibitively expensive, save on small areas of key importance. Drilling of seed is more economical. From central Utah northward into Canada, drilling among annual weeds has produced satisfactory grass stands, except where the species planted have been unadapted, or where droughts have been severe and soil conditions unfavorable. It has been less successful in the southern Great Plains. Experimental drilling of abandoned cultivated lands without previous soil preparation costs about 75 cents an acre in addition to the cost of the seed. In the Intermountain region it has been found that, with a narrow-width drill, slopes up to 60 per cent can be drilled on the contour, unless the lands are rough and uneven. On the steepest slopes (50-70 per cent), outrigger wheels proved useful in steadying the drill. By seeding in strips and actually drilling only one-third to one-fifth of the area, the drilling of gentle slopes is kept down to 35 cents to 50 cents an acre, and steep slopes $1 to $1.50 an acre.

Sowing with a hand broadcasting machine reduces the cost of seed distribution to about 35 to 50 cents an acre, but requires the seed to be covered by harrowing or brush-dragging at a cost of 50 cents to $1, or in rough or brushy areas by driving livestock around on it, to trample in the seed, at an estimated labor cost of 50 cents to $2 an acre. If a herd of sheep in the vicinity can be used there may be no extra cost for trampling in the seed.

Areas of paramount importance as watersheds justify more costly revegetation methods than those feasible for forage production only. Studies reveal various possibilities in the healing of such "sore spots," including fencing, seed-bed preparation, fertilizing, and great care in covering seed; or perhaps even the hauling of surface soil or transplanting.

Research is necessary to obtain information for the determination and ready recognition of requisite soil qualities, before artificial revegetation can be undertaken with scientific assurance, and a start has only barely been made in these investigations of basic soil and plant relationships. It is also necessary to find plants suitable for large eroded tracts on which the soils are too raw and shallow to be suitable for the better grasses.

Incisive investigations of forage species suited to various soil and climatic conditions are well under way at the Intermountain, and have begun at the Northern Rocky Mountain, the Southwestern, and the California Forest and Range Experiment Stations. A catalogue of the conditions under which 80-odd grasses will grow advantageously is one objective on 3,000 new experimental plots in the Intermountain region. Some of these plots are at high elevations, others at low; some on dry, others on moist sites; some on areas of preserved, others of eroded soil. Trials here and elsewhere show, for example, that a number of cultivated species, such as Kentucky bluegrass, timothy, and white clover, can be successfully reseeded on depleted mountain meadows in many parts of the West; that smooth bromegrass thrives in moist foothill zones in Utah

Idaho, and Nevada; that mountain brome, and slender and spiked wheatgrasses, grow well through a wide range of elevation and moisture; and that crested wheatgrass will succeed in the dryer Intermountain valley edges and foothills in the Snake River plains of Idaho, and also in the northern Great Plains, and in eastern Oregon and Washington, and is suitable for reseeding abandoned dry-farm fields in Montana. In the southern Great Plains and in New Mexico and Arizona, black, blue, and side-oats grama grasses and dropseed grasses have done best. Buffalo grass has, in the Central Plains region, revegetated from seed, runners, or pieces of sod. Preliminary tests in Nevada and Utah indicate that bulbous bluegrass spaced several feet apart on areas of downy chess increases at the expense of the latter grass. These examples indicate progress, but for many other desirable grasses, practically everything remains to be learned regarding their peculiar and specific adaptations and responses to the almost infinite variety of site conditions that exist in the range region.

Although the job ahead in artificial reseeding of denuded portions of the western range is tremendous, results in increased feed values already obtained experimentally fully justify the effort. For example, on a 12-acre tract on a deteriorated sagebrush foothill range near Ephraim, Utah, crested wheatgrass reseeded in 1930 now yields three times as much forage as similar unseeded range outside, and smooth bromegrass nine times as much. Numerous other examples of successful reseeding might be given.

Research has also begun to show the way to effective revegetation of abandoned cultivated land, at costs low enough to be practical. At the U. S. Sheep Experiment Station near Dubois, Idaho, dry-farm land abandoned to tillage and grown up to Russian-thistle has produced, after artificial reseeding, a stand of mature crested wheatgrass that has nearly tripled the yield obtained from adjacent well-managed native range. In 1937 the reseeded portion of an abandoned field on a Montana ranch yielded 2,263 pounds of forage to the acre, 84 per cent of it crested wheatgrass; the unseeded part of the same field yielded 1,112 pounds of low value weeds and downy chess.

Plant breeding as a means of improving range plants is being undertaken at Logan, Utah, by the Bureau of Plant Industry, in cooperation with the Utah State Agricultural Experiment Station and the U. S. Forest Service. Indications are that much can be accomplished through selection of natural strains of high-yielding, grazing-resistant, or otherwise desirable native species.

Results are encouraging. More and more stockmen, under the stimulus of government subsidy, are reseeding depleted parts of their ranges, using the methods and principles developed by research. But ahead lie "greener pastures" indeed. Better species for planting are being sought—native species by seed collection on the western range; foreign species through the Bureau of Plant Industry; and new or improved strains by plant-breeding. Costs of producing seed and of planting on the range are being lowered as new methods indicate that successful plantings can be attained without costly cultivation, and as more efficient machinery comes into use. Choice of species adapted to specific site conditions, and of planting methods which assure greater success under the semi-arid conditions where the problem is most acute, avoids costly failures of the past. Beyond these fundamental studies of establishment, lie studies of the most effective utilization, on a maximum sustained-yield basis, of the plant cover of ranges that have been produced by artificial reseeding. Man-made oases must not be permitted to drift back into man-made deserts.

RANGE-PLANT LORE DEVELOPED DURING DECADE

By W. A. DAYTON[1]

GRAZING capacity of range lands, periods and degrees of proper use, and class of livestock to which a particular range is best suited, are determined largely by the character and composition of the range vegetation and by the life habits and values of the plants themselves. During the ten years since the McSweeney-McNary Act was passed the Forest Service has begun intensive studies of some of its "key" range species. An example is black grama (*Bouteloua eriopoda*). This is a choice grass, originally the forage mainstay on numerous southwestern range areas, highly palatable and nutritious both in summer and winter, and valuable year-long, especially for cattle. The problem of its proper management is complicated by the long periods of drought in the region where it flourishes, by its having three methods of spread (seed, tillering, and stolons), and by the frequent poverty and low viability of its seed crop. Where overgrazing and other bad management have been tolerated, such vegetable riff-raff as snakeweed invade black grama stands. But conservative grazing on a sustained yield basis maintains black grama as well as, or better than, complete protection from grazing.

The welfare of herds and flocks is menaced unless poisonous plants are recognized and guarded against. In its studies of these the Forest Service has cooperated actively with the Bureau of Animal Industry. The poisonous plant problem is a complex one, as increasing knowledge increasingly reveals. Larkspur patches, very dangerous on cattle range, can sometimes be turned over to sheep to graze with impunity. Many lupines that in their early stages are harmless or even good forage are, as stockmen have learned to their sorrow, poisonous when in fruit. Cocklebures are poisonous only when in the seedling (cotyledon) stage. The immense genus *Astragalus* contains cultivated vegetables, valuable forage plants, and species that are highly poisonous, such as certain locoweeds of the western range. Moreover, at least one of its members (*Astragalus convallarius*) is a sort of Dr. Jekyll and Mr. Hyde of the range, with a "split personality" that sometimes makes it a very good forage plant, and at others virulently toxic. Research has revealed that its toxicity is dependent, in some cases at least, on the presence in the soil of selenium, to which it is highly receptive. Again, there is increasing evidence that range livestock poisoning may result when two plant species, individually innocuous, are eaten in combination. As "crab and ice-cream" to some human beings, they are concomitantly disastrous.

Soil protection, soil erosion, and supply of water for domestic use, irrigation, and hydroelectric power, are all intimately correlated with mountain range vegetative cover. For example, on the Boise watershed of southeastern Idaho, the replacement (through past overgrazing) of perennial grasses by annual weeds, such as kitchenweed (*Gayophytum diffusum*) and tarweed (*Madia glomerata*) is linked with increased run-off, loss of fertile topsoil, silted reservoirs and irrigation ditches, poorer livestock, crippled industries, bank failures, and lowered living standards for numerous individuals and communities.

A 224-page booklet of botanical, ecological, phenological, and economic notes on range grasses was issued by the Forest Service for use of forest officers in 1914. Probably the two most important of the publications of the Forest Service dealing directly with range plants and

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published since the passage of the McSweeney-McNary Act are *Important Western Browse Plants* and the *Range Plant Handbook*. The former was the first compilation ever issued of available information on range browse (shrubs, undershrubs, small trees, and woody vines). Although emphasizing palatabilities to domestic livestock and ecological requirements of the many kinds of browse, this publication also includes information on poisonous and medicinal properties, values for watershed protection and wildlife, and production of wood and edible fruits. The *Range Plant Handbook* evaluates for field workers who are not botanical specialists the relative importance of about 300 primary and 600 secondary "key" plants of western ranges, with regard to grazing, watershed protection, wildlife, recreation, and other uses. Moreover, the identification of the plants is facilitated by explanatory illustrations with key diagnostic characters.

The range plant herbarium of the Washington office of the Forest Service, greatly augmented during the past ten years, contains well over 80,000 specimens. This storehouse of information on range plants is one of the best annotated herbaria anywhere, and is recognized as the outstanding collection of western mountain plants. The herbarium, however, is not merely a priceless taxonomic collection; the information it contains is essential in the compilation and analysis of economic, ecological, and phenological data on range plants, and is reflected in numerous notes, both published and unpublished.

The specimens represent the flora of practically all the western national forests including the two Alaskan ones, as well as large areas of the public domain and other lands on which Forest Service officers have been or are conducting surveys or research. These specimens have been collected, in connection with their administrative or research duties, by hundreds of Forest Service officers. The Forest Service collection now embraces well over 1,000 genera and 8,000 species, and this number is being augmented continually. The goal, now within the range of hope if not of immediate expectation, is an estimated total of 1,200 genera and 10,000 species of native range plants on western grazing lands. This estimate, of course, includes flowering (seed) plants only, and takes no account of the vast host of cryptogams, or nonflowering plants.

The Forest Service collections have added over 100 species new to science, besides a very great number of range extensions. Interest is steadily mounting in the collection of plants from the more eastern national forests, purchased under the Weeks Act, and from eastern areas on which the forest experiment stations are conducting investigations. The eastern collections perhaps tie more closely to wildlife, planting, and other silvicultural problems, than to range grazing of domestic livestock.

This collection, together with the results of the great amount of field work it has involved, represents an extremely valuable storehouse of knowledge which, through painstaking study, compilation of results, and publication informally or in such official publications as those already cited, is continually supplying information of vital use in the application of range-management plans on 80 million acres of national forest range lands. This information is also of paramount importance in range surveys and studies, as well as the planning of range use, on much of the other 648 million acres of range lands in the West. Such important departments in the whole field of range management as the palatability and forage value of the plant cover on important ranges, resistance to grazing of forage plants on critical areas, and the many ecological aspects of range use, all make constant and compelling demands upon this treasury of range plant lore built up to its present stage of usefulness largely during the past decade.

THE FOREST GUARDIANS OF OUR WATERSHEDS

By C. J. KRAEBEL[1] and L. F. KELLOGG[2]

ON nearly 450 million acres, or about three-fourths of the forest land area of this country, the forest with its included areas of brush or chaparral is capable of exerting a considerable, and in most cases a major influence in the protection of our watersheds. What this might mean to this country can best be measured in terms of the vast expenditures of money, effort, and engineering skill that we are willing to make to obtain irrigation waters for fertile lands, to harness water power for industry, to secure constant and dependable supplies of pure water for our cities, and to protect our homes and industries from the ruin wrought by flood waters.

In most instances such expenditures are much greater than they should be because, through man's uninformed or reckless use of forest lands, the natural relationship between forests and waters—between precipitation on the uplands and the obstructive and absorptive efficacy of the vegetation cover on these slopes—has been destroyed or greatly impaired. Too often the very existence of this relationship has been disregarded. Too often the destructive flood, the dry stream bed, or the silted reservoir is regarded either as an inescapable condition or one that can be cured only by costly engineering projects.

Wide recognition has only very recently been given to the fact that a forgotten ally in this crusade to conserve, maintain, and control a sufficient water supply for the needs of the whole country is to be found in this 450 million acres of forest land, on which, once established under careful management, an effective tree and brush cover can operate at relatively little cost but with remarkable efficiency to hold the precipitation where it falls and lead much of the surplus into natural subsurface reservoirs. The 1936 Flood Control Act is unprecedented not only because of the size of the expenditures it authorized, but because it recognized that downstream engineering works for flood control must be supplemented by upstream measures for retardation of run-off and control of erosion on the watersheds. The Federal Soil Conservation Districts Act and the complementary state acts, and the recent appropriation bill for flood control activities of the Army engineers, make possible a start on the actual job of controlling our streams at the source. The latter Act states that "Not to exceed $4,000,000 shall be available for the prosecution, under plans to be approved by the Secretary of Agriculture, of works of improvement for measures of run-off and waterflow retardation and soil erosion prevention upon the watersheds of waterways for which works of improvement for the benefit of navigation and the control of destructive flood waters and other provision have been or hereafter may be adopted or authorized by law." Towards the solution of the complex problems presented by such a task forest-influences research must make a substantial contribution.

Management of the national forests in the interest of water conservation was one of the earliest obligations of the Forest Service. When Congress in 1897 set aside the forest reserves from the public domain, one of its stated purposes was to secure "favorable conditions of water flow." By far the greater part of the 16,500,000 acres purchased for national forests in the East under the Weeks Law of 1911 and the Clarke-McNary Act of 1924 was acquired principally for watershed protection.

[1]California Forest and Range Experiment Station.
[2]Central States Forest Experiment Station.

Forest influences are discussed in a number of early Forest Service publications among them "Forests and Water in the Light of Scientific Investigation," a monumental compilation of Old World data on this subject issued in 1912. The earliest actual research was the justly famous "Wagon Wheel Gap Experiment" in Colorado, conducted jointly by the Forest Service and the Weather Bureau. Begun in 1910, and completed in 1926, this study compared the behavior of the watersheds of two small mountain streams, one under natural conditions throughout the experiment, the other at first untouched but later denuded of its cover—chiefly aspen with some spruce. This study was modeled after a Swiss study on the Emmenthal watershed, begun some years earlier. As is often the case with research in a new field, both these studies raised more questions than they answered. They clearly revealed, however, the complexity of the influence of forests on streamflow and emphasized the necessity for isolating wherever possible the principal factors at work. The influence of herbaceous vegetation on run-off and erosion was studied from 1912 to 1931 in Ephraim Canyon in central Utah, and the need was here demonstrated for control of grazing on mountain watersheds.

The early paucity of data became painfully apparent when the Forest Service was called upon for a report on the relation of forests to the control of floods in the Mississippi Valley, following the great flood of 1927. This demand and the opportunity provided by the McSweeney-McNary Forest Research Act were the chief stimuli to the research program of the past decade. To date this program has been applied to parts of California, the Southern Appalachians, the Southwest, and the Intermountain region, with a little work in the upper and lower Mississippi Valley, and in the Rocky Mountains.

Methods of investigation have ranged from detailed laboratory tests, such as of the relative porosity of different soil compositions and forest litter, to observation of entire watersheds from 10 to 10,000 acres in extent. Some striking results have already been obtained from both laboratory and field studies. One is the discovery that forest soil, denuded of trees and brush and of the litter cover protecting the precious topsoil, becomes almost impermeable when rain muddies the surface and causes soil particles to stop up the interstices through which subsurface run-off normally percolates. Such findings were corroborated by large-scale tests. In the southern Appalachian Mountains a comparison of run-off from 22 small watersheds, during 1935-1937, showed the following maximum discharge rates from various cover conditions—a hardwood forest, 164 second-feet per square mile of watershed; abandoned farm land, 906; and completely denuded land, 3,836. Closely parallel results were obtained in California when the effect of a 12-inch rain was observed on burned and unburned chaparral-covered watersheds. Similar investigations of forest ranges in New Mexico and Idaho demonstrated that excessive depletion of natural cover, in this case by grazing, speeds up erosion to far above normal, with consequent loading of run-off waters with silt, the shoaling of streams, and the rapid sedimentation of reservoirs.

When super-floods follow prolonged storms of extraordinary volume and intensity, the control of forest cover upon run-off is less pronounced. Even under such conditions, however, the forest reduces erosion, and keeps flood waters relatively clear. Because municipalities, power projects, and irrigation works all require clear water, and because the silt burden in flood waters often causes the major damage, this partial control is very important. An example is afforded by the records of the floods of March, 1938, in Southern California. From a rainfall of 20 inches in three days, chaparral watersheds which had been burned only four years previously yielded erosion debris at the rate of 120,000 cubic yards per square mile of watershed; similar

watersheds burned 19 years ago yielded only 12,000 cubic yards; and watersheds burned more than 50 years ago yielded only 4,000 cubic yards.

Such results are of great significance, but the chief limitation of large-scale studies is the difficulty of isolating factors contributing to the results. For more intensive study, many sample plots of one-fortieth of an acre or smaller have been employed. Here more precise measurements can be made and a greater degree of control exercised.

One factor so isolated is the effect of forest litter, or humus soil cover, on surface and subsurface run-off. On oak-pine plots in the southern Appalachian Mountains from which litter was removed annually for three years the surface run-off increased 10- to 20-fold over that from adjacent undisturbed plots. Sample plots in Mississippi and Wisconsin revealed the ability of local forest cover, even of scrub species, when litter was undisturbed, to reduce the surface run-off to 2 or 3 per cent, as compared with 25 to 62 per cent from adjacent cultivated or fallow land. Eight years' observation of certain plots in California, covered with pine and lesser forest vegetation, has revealed that when annual light burning of the cover for 6 years has completely destroyed the accumulated litter, the annual seasonal run-off was increased 128 times, the volume of soil eroded was increased several thousand times, and the infiltration capacity of the soil was cut down to 35 to 15 per cent of the normal on adjacent undisturbed soil. On plots burned only once the regrowth of vegetation appeared to have fully controlled erosion 4 years after the burn, but surface run-off 6 years after was still several times greater than that from undisturbed vegetation. Hitherto it had been generally assumed that as long as a stream runs clear its watershed has been little damaged.

Digging still deeper, both literally and figuratively, into the phenomena of forest influences, the Appalachian and Northeastern Stations have been observing the numbers and activities of myriad but often microscopic creatures, particularly in the upper layers of forest soil, whose activities have been found to add greatly to its porosity and moisture-holding capacity. They have studied the effect of fire, grazing, and cultivation upon the number and character of these organisms and the time required for their populations in the soil to recover from the effect of such treatments.

In these and a multitude of other ways, forest-influences research of the past ten years has given a clearer understanding of how the watershed forests act to stabilize streamflow. Such stabilization is necessary not only to control floods but to assure better distribution of the water supply throughout all seasons of the year, to tide over drought periods, and to maintain dependable city water supplies, power sources, navigation, recreation outlets, and irrigation projects. In a few regions, this research has begun to give us also a knowledge of the degree of this stabilizing influence. Accurate measurements are imperative for the use of the engineer who designs reservoirs for storage or flood control, channel improvements, or other engineering works; nor are they any less essential as a basis for public and private expenditures in forest acquisition or forest management for watershed protection.

The forest-influences research already under way has accomplished much, but there is need to intensify and expand it, as well as to continue it for a sufficient number of years to cover all variations in climate which may reasonably be expected. It should also include adequate investigation and observation in all parts of the country. The broad sweep of the United States embraces many local climates, soils, and consequent forest cover; in each the influence of forests on streams and water will differ in kind and degree. Everywhere there is need for accurate factual information. This alone will enable this Nation to make full use of two of its greatest natural resources—forests and waters.

KEEPING OUR WILD-LAND SOILS IN PLACE

By GEORGE W. CRADDOCK[1]

LITERATURE records the words of an unknown poet eulogizing the stability of the soil mantle on Mother Earth in his utterance: " 'Tis the imperishable storehouse of Eternity." Such a concept of the soil might well have come from the lips of our forefathers 300 years ago when they disembarked from ships and began the task of building an empire. For at that time, and even in later years in other parts of the country, the pioneers had at their disposal a mantle of virgin soil which to their eyes must have seemed as unchangeable as the climate and the underlying rock.

It is inconceivable, however, that the Muses could move anyone to such encomium for the constancy of the soil today. For whether we begin at Plymouth Rock and follow the course of empire westward, or whether we start in the heart of our newest frontiers and back-track along this trail, we find gullies, pedestalled plants, and newly exposed subsoil on the one hand, and reservoirs, river channels, and harbors choked with freshly born sediments on the other, bearing silent witness to the vulnerability of the soil to unleashed forces of wind and water.

Our soils did not go on the march overnight. The impairment of their normal stability began when the first settlers cleared the forests and planted their crops, thus disturbing the relationship between climate, soil, and living things which had been ages in the making. But the later processes of impairment were insidious—so subtle, in fact, that the eyes of a people accustomed to prodigality were unable to detect any change. The first faint warnings of slightly decreased crop production and slightly increased turbidity of our streams went unheeded. It took spectacular dust storms, land slumps, floods, and mud-rock flows to provoke us to action. Now that all these things have happened, keeping the soil on duty where natural processes built it up through countless ages, is a matter of grave concern, not only with respect to our fields and pastures, but for our wild lands as well.

For years before the McSweeney-McNary Act was passed the Forest Service, aware of the tremendous soil losses that were occurring on the 160 million acres of national forests already under its jurisdiction, had begun to reduce the losses by fire protection, proper range management, control of logging operations, reforestation, and range reseeding. The new law gave impetus to research on erosion and made possible a broader and more intensified attack upon the job of keeping our soils in place. In some of the more serious problem areas throughout the forest and range regions of the country new methods of control were given trial, and detailed studies were begun of basic causes and processes.

The enormous amount of work done in recent years on American highways—not only construction of new roads, but relocating, widening, and grade improvement of old—has involved in the aggregate vast quantities of soil. From countless cuts and fills tons of it have been slipping away after heavy rains and rapid snow-melts. Research on this vexing problem found a way of fixing the exposed slopes along mountain roads in California by means of brush wattles and the establishment of vegetation. Similar problems are being met with equal success in the South and East through the

[1]Intermountain Forest and Range Experiment Station.

development of effective methods of planting quick-spreading grasses and vines.

From abandoned farm lands in the South the topsoil has been washed away, and whole fields have been cut by gaping gullies. As a result of intensive research, successful plantings of loblolly and shortleaf pine are today not only halting the extension of gullies but are actually recovering these waste lands and converting them to productive forest properties.

Blackened scars left by fire on our brush- and forest-covered mountains all too frequently mean destructive floods of debris-laden water following the next heavy rain. Fire is still a primary cause of erosion, but its menace is gradually lessening through the development of increasingly effective control measures. For example, the terrible threat of these floods has been greatly minimized in southern California by the discovery that burns in brush fields can be quickly started on their way to recovery by reseeding them artificially with common mustard. In forest nurseries throughout the country, rapid strides are being made in the development of planting stock and planting methods that will insure quick development and good survival of plantations on burned-over areas.

On the shifting prairie soils of the Middle West, foresters are now showing that the planting of narrow strips of trees at strategic locations will save whole fields from the scourge of wind, and at the same time provide farmers with fuelwood and posts.

The increased frequency and severity of destructive mud-rock flows from "sore spots" on our western range lands, and the loss, through accelerated erosion, of productive top-soil from two-thirds of this vast domain, were thoroughly alarming. Research has demonstrated that the restoration of even a little grass by careful artificial reseeding, the construction of miniature contour trenches, and the proper control of livestock use on these "sore spots" will correct these conditions. Moreover, techniques have been developed for artificial reseeding of eroding slopes as steep as 70 per cent at less than one-third the cost of previously known methods, thus opening the way for an extensive and much needed program of rehabilitation of the western range lands.

While the direct attack on some of the more serious erosion problem areas in this country has proved to be highly successful, this represents only one phase of the contribution research has made toward keeping our wild-land soils in place. For in coping with these immediate problems, it has been necessary to dig deeply into the causes of widespread accelerated erosion. This has involved the recognition and use of the physiographic approach, which rests upon the concept that in the soil mantle, the land profile, and the structure and composition of stream channels and deposits, is written the history of past gradational processes. Study of these physiographic features makes it possible not only to evaluate current erosion phenomena by comparing them with those of the past, but also provides a basis for ascribing the causes of new erosion epicycles, and for developing feasible and effective control programs.

This concept was used with outstanding success in controlling a serious erosion and flood hazard which developed in recent years along the Wasatch Front in Utah. Here observations revealed that floods of a few hours duration in each of six short, steep canyons had cut far below the formerly stabilized stream channels into previously undisturbed sands and gravels, and had deposited a quantity of boulders and other debris on the valley floor far in excess of the amounts which had been deposited by these streams during the past 20,000 years.

Starting with this clear-cut evidence of a drastic change in the gradational processes of these streams, the floods were traced by means of telltale gullies to their

sources. These were found to be tracts seriously depleted by fire scars, or bedgrounds and other livestock concentration areas in the headwaters, amounting in the aggregate to only about 5 per cent of the watershed area. By proper treatment of these restricted "sore spots," rapid surface run-off and erosion were prevented, the normal watershed function of the land was restored, and the threat of continued floods eliminated.

Similar methods of analysis have revealed the occurrence of accelerated erosion in the Colorado and Rio Grande River drainages and the need for an extensive program of run-off and erosion control work there. The physiographic concept, together with other principles and techniques recently developed by research, is also being used effectively in the analyses of flood and siltation problems encountered by the War and Agricultural Departments in their joint studies under the current Flood Control Act of 1936.

From these and other studies have come a clearer concept of the limitations of the soil resource and a modern philosophy of wild-land conservation. The unproductiveness of newly exposed subsoil and the slowness with which fertility is restored to impaired areas have driven home to all conservationists the basic truth that our soil resource is a product of the ages. Once destroyed, it is gone, in so far as present generations are concerned. In most regions, therefore, managers of forests and ranges modify their silvicultural and utilization techniques to meet requirements for conserving the soil, without which tree growth and forage production are impossible.

Foresters have contributed substantially to the development of proof that plant cover plays an important part in keeping soils at home. Pioneering in this field with carefully controlled experiments, they have shown conclusively that the plant and litter mantle is under many conditions the most important single factor influencing run-off and erosion. This is now widely recognized, and today sound management practices on watersheds are being given consideration coordinately with engineering works farther downstream.

Forest research has noted that one of the major reasons for the present widespread occurrence of accelerated erosion is the naturally high erosion potential of our wild lands. It has found that the rains of cloudburst intensity that are common on watershed lands, cause from 50 to 500 per cent more erosion than ordinary storms. Under identical conditions of rainfall, soil, and plant cover, it has also found that steeper slopes of wild country more susceptible to erosion—60 per cent slopes yielding 6 times more eroded material than 20 per cent slopes. It has brought out forcefully how close to instability are the soils of many of our wild lands and has emphasized the need for making proper allowances for the normal as well as the abnormal forces affecting this valuable resource.

Although the foregoing has shown that stopgap measures have been devised for halting erosion on many of our more seriously eroding areas, there is no doubt that this destructive process is continuing unheeded in many places because simple and effective ways of recognizing incipient erosion have not yet been developed. Moreover, the normal erosion potential of our wild lands is practically unknown, and until this phenomenon is better understood engineers will continue to be handicapped in planning and designing flood control and other stream improvements by the inadequacy of information as to how much run-off and erosion can be expected from the wild lands above their structures.

Here are broad fields for new and original research. Other problems not yet solved include the utilization standards to be set up for forest and range lands to maintain the soil in stability and optimum productivity, and less expensive methods of controlling erosion than those so far developed.

EFFECTS OF FORESTS UPON LOCAL CLIMATE

By C. R. HURSH[1] and C. A. CONNAUGHTON[2]

EVERY stand of timber, every cut-over area, every burn, has its own peculiar climate. Within the few acres of a cut-over area, for example, it may be much hotter during the day and somewhat colder at night than in the region round about; the wind may blow faster; more rain may fall; snow may be deeper, but melt earlier in the spring. This local climate exists there because the trees which cover the rest of the region are absent. In turn, the local climate vitally influences forest growth and regeneration, as when in the foregoing example higher temperatures at the surface of the soil may spell death for newly-germinated tree seedlings that might otherwise survive to reforest the area.

One of the first investigations in forestry in America was a general study of the effect of the forest on climate. These early empirical observations supplemented by studies in various foreign countries, indicated that the climatic factors most directly affected by the forest are temperature, amount and velocity of wind, evaporation, humidity, and precipitation, both rain and snow. More recent studies, better designed and more carefully thought out, have been undertaken in several regions of the United States under the authorization of the McSweeney-McNary Forest Research Act of 1928. Although present knowledge does not justify the belief that forests materially influence the general climate over vast areas, ample evidence is available to demonstrate that they do have a marked effect on the local or environmental climate. In general, the larger the area of forest the greater its influence on climate.

Opportunities for comparing the climate of similar contiguous areas of large size differing only in the presence or absence of forest are rare. However, one exists in eastern Tennessee, where in relatively recent years an area of 7,000 acres, in Copper Basin, once heavily forested, has been completely denuded by smelter fumes. Surrounding this island of absolutely complete denudation is a zone of 12,000 acres which supports a stand of perennial grasses. This is in turn surrounded by a hardwood forest of approximately the same composition as that which originally occupied the basin. Two years' records in these zones show that, in both winter and summer, average daily temperatures dropped 3 or 4 degrees F. lower in the forest than in the denuded zone, and did not generally rise as high. Average wind velocity was 7 to 10 times as great in the denuded zone in winter, and 34 to 40 times as great in summer; evaporation was twice as great in winter and 7 times as great in summer. Such differences in temperature, wind velocity, and evaporation associated with a forest cover are easily explained on the basis of the insulating and mechanical effect of the trees. Astonishing, however, are the differences in precipitation. In the winter of 1936, precipitation was 17.5 per cent greater in the forest than in the denuded zones, and in the preceding winter, 25 per cent greater. In both summers it was over 28 per cent greater. This record, although of extreme interest, is so short that until further study and analysis have been made great caution must be used in classifying "rain production" as an attribute of the forest cover.

In regions where spring floods are caused chiefly by rapid melting of deep snows, the influence of forest cover on the accumulation and rate of snow melt is of very great importance to local and distant populations. Studies in the Inter-

[1]Appalachian Forest Experiment Station.
[2]Rocky Mountain Forest and Range Experiment Station.

mountain region have revealed that an appreciable portion of the annual snowfall is retained and dissipated by the tree crowns, the amount dissipated varying directly with the height and of course the density of the tree crowns. Of particular significance is the fact that while small openings in the forest were effective as snow-accumulating areas, they did not appreciably increase the rate of snow melt. Research on snow conditions at several western forest experiment stations has demonstrated conclusively that a forest cover both intercepts snowfall and retards snow melting. The studies to date encourage silviculturists in their belief that well planned methods of cutting can maintain a forest cover which will collect the maximum amount of snow, and that forests may be used simultaneously for wood production and for effective stream flow regulation.

The amount of rainfall lost to the forest floor because of interception by tree canopies has been measured at several forest experiment stations. Such intercepted rainfall obviously does not contribute to flood heights, but on the other hand does not raise low-water flow of streams or nurture the trees that intercept it. Batteries of trough rain gauges erected beneath tree crowns, and collar-like catchments placed around the boles, gave evidence that, for the 40-inch rainfall belt of the Southern Appalachians, 12 to 18 per cent of the total annual precipitation was intercepted in the forest type studied. This amount includes one to three per cent of the total precipitation which later reached the ground by flowing down the tree boles. It is evident that interception by vegetation canopies is a very significant factor in the water cycle.

The influence of forests on local climate is nowhere better illustrated than in shelterbelt planting in the Prairie-Plains region. Intensive studies of the past four years show that belts of trees 50 feet high, a quarter of a mile apart, and with an occasional row or narrow belt at right angles to the main series, will reduce wind movement over the intervening land by 10 to 50 per cent. A belt of optimum (not maximum) density may reduce the movement over adjacent ground as much as 70 per cent. Such lessening of wind movement markedly reduces soil-blowing, which in sandy areas is regularly destructive, even in comparatively wet years. The shelterbelts also decrease evaporation, but owing to a combination of causes, they can only slightly delay—rarely prevent—the exhaustion of soil moisture by prolonged drought. It also must be frankly stated that a belt of trees, like any other crop, will appropriate to its own use all the water it can get, within limits, and that possibly trees drain the subsoil of its moisture more deeply than most field crops. Current research will, it is hoped, reveal what species of trees are least extravagant in their use of water when overall size, total foliage, or some similar unit, is the basis of comparison. Some species now dubbed "drought resistant" may survive not because they use less water than other species, but because they possess some peculiar ability to send their roots farther in search of it.

The foregoing studies are only examples of the considerable volume of research into local climates which has been conducted in a number of forest types. Everywhere the effects of forests on local and environmental climate are marked. Generalizations concerning these effects are, however, difficult. That wind velocities and rates of evaporation are lower in the forest than outside of it appears universally true. But broad pronouncements concerning temperature, or even precipitation reaching the forest floor, require so much qualification as to be meaningless; statements must be confined closely to specific conditions.

Because man has it in his power radically to alter the forest, and in America

has done so at least in one direction on a vast scale, the knowledge being obtained of the relationships between local forests and local climate is basic to good silviculture, forest protection, and watershed management. For example, an intensive study of the influence of forest cover on local climate and survival of tree seedlings in the Northern Rocky Mountain region showed that the amount and kind of regeneration can be modified by careful manipulation of the overwood. By clear cutting, the local climate has been modified to the extent that western white pine and lowland white fir regeneration are increased at the expense of western red cedar and western hemlock. In other habitats, however, clear cutting induced such extremes of climate that no regeneration took place. Moderate shade was needed to ameliorate the influence of insolation on severe sites.

In southern New Jersey, an overwood, by narrowing the temperature range, reduced losses of chestnut oak seedlings. Reduction of losses from frost were particularly noticeable in the forest, where critically low temperatures were not reached. Such studies emphasize the fact that in better knowledge of local climate as it is influenced by forest cutting the silviculturist has at his hand a tool which can be applied to encourage desired regeneration.

Modification of local climate by removal of forest cover tends to increase fire hazard. In the Northeast it has been found that because of higher temperatures, greater wind movement, and greater evaporation in the open, surface duff becomes inflammable after a rain approximately seven and one-half days earlier in the open than under timber. Extreme fire hazard in northern Idaho on cut-over areas is explained in part by the study of local climate. Because of lower maximum temperatures and other local climatic conditions, fire danger is generally much less in the forest than in cut-over areas. Fire danger does not, however, increase proportionately with the amount of timber removed until a considerable portion of the stand is removed. A partial crown canopy left at the time of cutting would avoid the climatic extremes which follow clear cutting. Where clear cutting is necessary, "green firebreaks," or densely vegetated strips of uncut forest, are recommended for fire protection.

In watershed management the complete significance of forest effects upon local climates is by no means yet determined. But research at the various forest experiment stations has shown that the control, by modification of the vegetation, of interception of rain and snow, evaporation, and transpiration may have a very important place in watershed management. Measurements of stream discharge from forested drainages show a marked diurnal fluctuation in flow that is attributed to vegetation's greater demand on soil water, through transpiration, during the day than at night. During periods of summer drought the reduction of flow by vegetative use might conceivably cause a critical loss in municipal and industrial water supplies. In a planned program of flood control, maintenance by the forest of maximum infiltration capacity of the soil, to minimize storm run-off from the drainage areas, must be weighed against transpiration losses.

Knowledge of the intricate relationships between local climate on the one hand, and forests or other wild-land vegetation on the other, is still extremely meagre when the number of forest types which have been studied is compared with the total number of important forest types in the United States. Wherever forests are needed for wood production or outdoor recreation, and wherever waters are required for domestic and industrial purposes, or for navigation, irrigation, power production, or other human use, this knowledge is essential to wild-land management in man's behalf.

WOOD QUALITY—A REFLECTION OF GROWTH ENVIRONMENT

By ARTHUR KOEHLER[1]

TIMBER value in a tree is only a byproduct of its struggle for survival —a special case in which adaptations of nature happen to overlap one or more of the requirements of human consumption. Within every species manifold variations of wood characteristics occur, the importance of which is being more clearly revealed as research establishes more definite linkage between properties and uses.

Even within a given tree, wide gradations of properties may be found, whereas typical samplings of the species, or even the genus, may show remarkable constancy in "average" structure, chemical composition, and properties. Cumulative evidence indicates that major causes of variation within a species are to be looked for in the field of ecology—the relation of wood quality to the conditions of tree growth. The practical value of such studies lies, of course, in their application to timber management, to the end that variations may be limited and wood properties brought into line with requirements in regulated rather than haphazard fashion.

To determine control principles will be a labor of many years, perhaps of generations, with the cooperation of many trained observers. The undertaking in America is only beginning, and workers are very few. Old notions as to causes that may have affected wood quality in the virgin forest must give place to knowledge of what can be accomplished with the second-growth crops that will henceforth be the forester's stock in trade. In view of the magnitude of research needs in this field, the results accomplished by the Forest Products Laboratory in the short space of 10 years are necessarily limited. Nevertheless information of significant interest to both timber growers and wood users has been obtained.

The widespread belief that state lines or regional boundaries mark off areas of "good" and "poor" quality in the distribution of a species is often little more than superstition.

Differences in locality obviously can have no influence on tree growth unless there are accompanying differences in site factors. While it is true that quality differences exist for species that grow under widely different conditions of soil or climate, investigations of ash, hickory, and other species commonly questioned in this regard show that the importance of locality is generally overestimated, and that greater differences can be found in different trees of a species in the same stand than in averages of even widely separated stands.

That site has an important bearing on the form, properties, and usefulness of timber cannot be questioned, although data are as yet confined to a few particulars with regard to water supply. In the extreme case of ash, tupelo, and some other species growing in the overflow bottomlands of southern rivers, swelled butts are developed up to about 12 feet above ground, in which the wood is so light, soft, and weak that it is of no account for the ordinary uses of these species. Other species, such as cedar elm, Nuttall oak, water oak, and overcup oak, growing in the same forest areas, produce wood of normal quality and are therefore to be preferred in the choice of species for such sites. A different but still unfavorable reaction is found in ash growing on very moist but not overflow land, which would rank as No. 1 site. The butts of the trees produced wood which, although high in

[1]Forest Products Laboratory.

specific gravity, was low in stiffness and quite unfit for articles subjected to considerable bending in use.

Again, the wood of some of the second-growth ponderosa pine growing in California west of the Sierras, under what are considered optimum moisture conditions so far as volume production is concerned, has such wide and conspicuous summerwood that it is objectionable for uses requiring evenness in grain. In this respect it is quite unlike the soft-textured ponderosa pine growing on dry lava beds on the east side of the range. A generalization that is clear from the work thus far is that the best sites for volume production do not necessarily produce the best wood.

On the other hand, the importance of available soil moisture in its relation to rate of growth and wood quality was brought out strikingly in some longleaf pine trees in western Florida. They grew on deep sandy soil, and, although the rainfall averaged about 60 inches a year, they grew slowly and produced only narrow bands of summerwood. As a result of pumping additional water around the trees during three successive growing seasons, the width of the springwood was increased by one-half and the width of summerwood by 1½ times the average for the 14 years preceding, whereas in unirrigated check plots there was only a slight increase. Similarly, jack pine from plantations in the Nebraska sand hills was found to have poorly developed summerwood, in that it was narrow and its tracheids often showed little or no thickening of their walls—again apparently on account of lack of sufficient soil moisture. Wood of this type is relatively weak.

Stand density, or competition from other trees, has been found one of the most important factors influencing wood quality, and fortunately it is the one most susceptible to control by the forester. It not only affects rate of growth, but also shape of bole, knottiness, width of springwood and summerwood, percentage of heartwood, specific gravity, and numerous other properties, such as strength, shrinkage, and tendency to warp.

The effect of stand density is particularly evident in comparing virgin growth with second growth, or, more accurately, forest-grown trees with open-grown trees. Maple, yellow poplar, oak, ash, and hickory were found to have somewhat heavier and considerably harder wood in second-growth than in old-growth trees. In the Appalachian Mountains, where the old-growth oak is noted for its soft texture, the second-growth oak was appreciably harder and denser. For the uses to which certain species are usually put, the greater density of the second-growth timber is an advantage, for other species and uses it is a disadvantage.

More variation in density and strength was found in virgin-growth than in second-growth timber of some species, because crowding of the virgin stand in later stages of growth caused the putting on of appreciable amounts of slow-growing wood that was low in density, whereas in the second-growth material examined the stage of crowding had not been reached. If the second growth were allowed to reach a high age and to close in without thinning, it undoubtedly would show even greater variation than growth of the original forest. In all the hardwoods investigated the process of change from rapid to slow growth seems to be a highly important factor in lowering density and its associated wood qualities. For example, young ash and hickory trees that began their growth slowly produced almost as dense and strong wood as those of faster growth. It was when the fast-growing trees were slowed down as a result of crowding in later life that they produced inferior wood.

Among the conifers, southern pines which grew very rapidly were found to produce wood low in specific gravity, brittle, and with excessive longitudinal shrink

age. For all species it would appear to be good practice to keep the stand dense enough in early life to avoid very rapid growth, and later to thin the stand so as to maintain or increase the initial growth rate. Wood so produced is more uniform in properties, remains reasonably straight in seasoning and use, has a minimum volume of knotty wood, and brings a good price.

A reading of the life history of knots in several species of pine showed that in white pine and red pine the branch stubs producing dead knots persist much longer than in the southern pines—in fact so long that no clear wood can be expected in the northern species in any reasonable rotation period, unless pruning is resorted to. In the southern pines the dead branches decay and break off sooner. To what extent the difference is genetic, that is, a species characteristic, and to what extent it is due to differences in climate that hinder or promote decay has not been determined. Although close spacing hastens the age and limits the size at which the lower branches die, it appears to exert no appreciable influence, in species such as white pine, in causing the early or close shedding of the dead branches.

Compression wood, wide-ringed material of abnormal properties, is found on the lower, or compression side, of branches and leaning trunks of all coniferous species thus far examined. That it is the result not of actual stress, however, but of some associated factor, has been demonstrated by the fact that it forms even when the compressive stress is relieved by supporting leaning trunks and branches. The degree to which compression wood develops is found to be contingent on the degree of lean of trees and on the rate of growth. In vigorously growing trees having inclined trunks, compression wood is more pronounced than in trees of slower growth having the same amount of inclination. Because compression wood is brittle, shrinks excessively longitudinally, causes warping, and does not even make satisfactory pulp, forest management measures should hold its formation to a minimum through the elimination of leaning trees—especially where selective logging is practiced, with its resultant increased rate of growth of the residual stand.

Foresters already have learned a great deal about volume growth of trees and how it may be increased; of late years much interest has been shown in developing hybrids or races that will grow rapidly and thus attain merchantable size in a comparatively short time. If, in addition, simple and dependable methods can be developed for producing timber of satisfactory quality from the various commercial species, timber growing should become a far more profitable enterprise than it has been in the past. Mineral and synthetic materials are refined and developed in industrial plants. The forest is nature's wood factory and refinery. Only by increasing knowledge of the ecological factors of wood quality can our new forests be made to function at their best efficiency in this regard, and their product fitted to render the greatest service to society.

WOOD—CONSTRUCTION MATERIAL OF PRESENT AND FUTURE

By J. A. NEWLIN and L. J. MARKWARDT[1]

To a degree practically unmatched elsewhere, wood construction has set the stage of civilization in America. Ready workmanship has fashioned forest material into the thousandfold structural and fabricated forms essential to the Nation's development—into housing for the people, transportation facilities, farm and commercial buildings, and all manner of equipment and conveniences. These uses of wood are of the highest importance in both volume and value. The economic and social needs to be served are basic. America, a nation of forests, should look forward to continued and more adequate service of forest material in meeting modern constructional and engineering requirements.

The foundation of proper and efficient use of wood for such purposes is accurate knowledge of its mechanical properties—its strength in tension, bending, compression, and shear, its toughness, rigidity, and other factors that determine its resistance to all kinds of stresses. In these respects, as in others, wood was for long the "unknown material." Variable factors of species and growth were not accurately accounted for in strength determinations, and the rough estimates and traditional practice common in the past have led to the wasteful and unsatisfactory use of untold millions of feet of timber.

To supply dependable data, it was first necessary for the Forest Products Laboratory to devise proper mechanical and statistical methods for evaluating strength properties and then to proceed with a long and laborious testing program. The general result of this work has been to place wood on a technical footing with other engineering materials. Hundreds of thousands of tests have defined and differentiated the various kinds of strength of more than 160 wood species, including all the more important woods produced for the Nation's markets. Both the methods and the results of this research have been adopted as standard by engineering authorities in America and abroad. A thoroughgoing analysis has been made of the influence of moisture on mechanical properties of wood and an exponential formula developed for moisture-strength adjustment of the data previously published. The work applies specifically to cases where moisture is uniformly distributed throughout the cross section.

On a foundation of known strength properties, research can build new and improved systems of design, construction, and material selection. Means of fastening wood parts together command serious attention, because the joints of a structure or fabricated article of wood are usually its critical points. Here so simple a device as the common nail takes on a special interest, because service, safety, or life itself may depend on its holding power. Comprehensive tests have made available for the first time reliable data on both lateral resistance and resistance to direct withdrawal of nails, as well as a better understanding of factors of size and shape of the nail as they affect its holding power and tendency to split the wood. A nonroyalty patent has been taken out on a new type of surface treatment of a nail not only to increase its holding power but also to make its grip relatively permanent. Likewise investigations of joints employing wood screws, lag screws, and bolts

[1]Forest Products Laboratory.

have established safe loads for various sizes of these fasteners in different species of woods.

Strivings toward a new order of efficiency in timber construction are represented by the introduction and development of modern metal connectors. These consist, in general, of metal rings or plates or wood disks that, when embedded partly in each of two members and held in place by the tightening of a central bolt, transmit load from one member to the other. Design data for such connectors, of various sizes, have been obtained relating to their use with important structural wood species. The influence of various details, such as the proper spread of ring and the minimum side and end margin of the wood to develop optimum strength of joint, have been explored. A more secure place has thus been established for wood in modern engineering. Shop fabrication of structural parts with assembly at the site has been made practical. Forest lookout towers of wood built with modern connectors are now in service; also self-supporting radio towers, 300 feet and more in height; timber arches, bridges, and roof trusses of greater spans than any previously built; and like structures of a size usually associated with steel or reinforced concrete construction.

The results of many years' study of structural timbers and the influence of defects on strength culminated within the past decade in the development of a practical and technically sound system of structural grading rules. These rules, since adopted by such organizations as the American Society for Testing Materials and the American Railway Engineering Association, have also found their way into commercial rule books of lumber associations. Whereas lumber grades commonly are based on the appearance of the piece, without regard to strength, the structural grades take into consideration both the size of the knots and other characteristics and their location with respect to stress distribution. The application of the rules permits the use of definite working stresses for design with specific grades and species.

Associated with structural grading was the study of large-sized columns of different slenderness ratios, to determine the effect of defects, to establish column formulas, and to check the grading rules. The new Forest Products Laboratory column formula, a fourth power parabolic equation for intermediate columns, has filled a long felt need and has already received wide circulation in engineering and architectural literature.

Also of interest and importance in structural timber use was the study of the influence of checks on strength. New formulas were worked out for the design or strength appraisal of seriously checked beams. Their wide use has been a salutary factor in encouraging the use of wood for bridge stringers and in preventing needless replacements. Much light has been thrown on hidden mechanical principles as a result of research on wooden airplane parts. The findings have sound application in other fields where design and service requirements are exacting. They include an analysis of the conditions of instability of wood members, as well as new methods of calculating the strength of continuous beams and the strength of shaped members in bending, compression, and torsion.

Perhaps no other single factor has been responsible for such significant advance in the field of modern wood construction as the development in glues and gluing technique. Laboratory studies have shown that beams, glued up, with the laminations either horizontal or vertical, develop the full strength of a solid member. An intensive study of laminated arches has given the technical data necessary for design. Following the erection

at the Laboratory of a service building with laminated arches, about a hundred other buildings incorporating the principle have been built by private enterprises in various parts of the United States.

Advantages of laminated construction are the use of smaller lumber, the possible use of a portion of low grade material, the more effective seasoning made possible by smaller stock, the fabrication of members of practically any desired size, and the production of structural units practically free from the checks so characteristic of solid wood in large sizes. The use of this construction permits the achievement of excellent architectural effect, at a cost to compete favorably with that of other materials.

Plywood, the thin and resilient layered material produced in quantity today, offers possibilities as yet unmeasured for the modern age of wood utilization. Improvements in glues and gluing are enhancing its adaptability. Since it is relatively light, resists splitting, and can be made up in sheets much larger than boards sawed from the log, it is suited for rapid and efficient use in many types of construction. Some of its uses, established or tentative, are in house ceiling, flooring, and sheathing, concrete forms, automobile floor boards, trailer bodies, and passenger-car interiors.

Such a material necessarily presents problems of development in which research can cooperate to marked advantage. Its investigation leads into many studies, such as gluing, moisture proofing, fire-resistive and other treatments, and the cutting of the veneer plies, as noted elsewhere. In the present connection are considered its mechanical properties and a special application in house construction.

From the standpoint of stress distribution under load, plywood embodies an already complex anisotropic material, wood, and makes it even more complicated by redistributing it in thin layers, with the grain of alternate plies at right angles. Add to this pattern the diversity possible through variation in thickness of individual laminations and the combination of different species, and the problem of strength calculations becomes intricate to the last degree. Mathematical analysis of plywood brings into play a barrage of fundamental properties, many of which remain to be evaluated. Intensive studies are under way to clear up these matters and to check the mathematical principles involved by the results of a thorough testing program.

With an acute housing shortage facing the Nation, the potentialities of service confronting wood and the obligations of research with respect to the material are manifest in full measure. The applications of general strength and structural data to problems of the small house are many, and studies in the specific field of housing assume major importance.

Full-scale wall tests have shown the relative resistance of different types of construction to racking forces. These tests were aimed at bringing out features of construction which tend to make frame dwellings and other small frame buildings substantial structures, resistant to wind stresses, economical, and free from excessive maintenance costs. They showed, for example, the four-fold superiority of diagonal over horizontal sheathing as regards rigidity.

For several years there has been under development at the Laboratory a system of all-wood prefabricated house construction aimed at exploring some of the possibilities of unit construction. Taking a cue from the aircraft industry, where strength and economy of material are paramount, panel units suitable for floors, ceilings, and walls were developed with stressed coverings of plywood. This was followed by studies directed toward the solution of various technical problems, such as improved fire resistance, incorpo-

ration of moisture barriers, the use of synthetic resin-bonded plywood, and the like. The results of these developments have been incorporated as far as possible in two experimental prefabricated houses recently erected. While much of the developmental work has centered around plywood, as indicated, the consideration of lumber has not been overlooked. A number of prefabricated units employing lumber as the principal material have been constructed, and further developments are under way.

The studies described, and many others which must be omitted for lack of space, have not been without their influence in modernizing the technical position of wood and adapting it to structural requirements of the present age. The duty devolving on research to insure the proper use of forest material in this field is vital.

IMPROVED HARVESTING AND UTILIZATION OF THE CURRENT TIMBER CROP

By C. V. Sweet[1]

THE basis of timber supply is changing, and the practices of utilization must change with them. Virgin stands are giving place to second growth. Both the large and the small owner are increasingly concerned with questions of the utility and sales value of the smaller logs, thinnings, knotty or otherwise defective trees, and little-used wood species.

In times past, much inefficient utilization of the timber resources has wrought waste of material, dissatisfaction to the user, and eventual net loss to the forest owner. Tangible returns from forest management under such conditions are an illusion, and in the present growth situation there is tenfold need for care and efficiency in harvesting and utilization methods. To aid in bridging the economic chasm that too often lies between the tree and the satisfied user of wood products is a problem of many interesting phases.

Work by the Forest Products Laboratory and by the products offices in the West has provided those concerned in the management of forests with handbook data on timber quality, in terms of lumber-grade yields by log and tree sizes, for the important hardwood and softwood species. More than 50 logging and milling operations in all forest regions have been intensively studied by production steps from the stump to the lumber pile. The production cost data that have been obtained, along with the grade-yield data, have special application to selective logging, the story of which is told elsewhere in this issue of the Journal.

Standard log grades which both mill buyers and sellers, particularly farmers, can use advantageously have never been recognized outside of a limited log market in the Pacific Northwest. While log-buying mills in the East have had their own specifications as to what constitutes a No. 1 or a No. 2 log, such specifications have meant little to either purchaser or seller. No adequate basis of fact has existed as to exact relationships between visible external characteristics of different kinds of logs and their effect on the grade of lumber procurable from them. A new principle for grading hardwood logs has

[1]Forest Products Laboratory.

been developed that results in elimination of undesirable overlapping in values in the different log classes. It is based on the volume of usable material between defects rather than on number and size of defects. Previously many so-called No. 1 logs did not cut out as well as some No. 2's or even No. 3's.

A basis or grading is in evolution whereby pulpwood can be sorted according to those variables of growth, density, knottiness, and the like that pulp and paper research finds to be important to diversified production, particularly in the case of southern pine. Farmers and other timber growers must be given, if possible, a basis for so sorting their wood that it can be used and priced to the best advantage.

A radical change in timber-harvesting practices lies in the recent turn to the logging of small and second-growth stands by truck and tractor. Forest Service investigations have disclosed some of its advantages and disadvantages. Studies in all regions of the country show that truck logging, properly used, is a great aid to intensive forest management and selective cutting, but that without proper measures of control it results in abuse of the resource. The adaptations of truck and tractor logging to proper forest management are merely beginning to unfold.

The utilization of second-growth trees, greatly accelerated by the recent introduction of truck logging, has brought into special prominence the small mill, particularly of the portable type. Its forestry effects, likewise, are good or evil, according to how its practices are controlled. It can and does undercut the large mill, both literally and figuratively. Some small advance has been made by the Laboratory, working through departmental extension agencies, and by others, in putting into the hands of small-mill operators practical means of reducing waste in cutting and in faulty processing and marketing steps. As a more radical means of avoiding the obvious difficulties of the small-mill situation, designs for a new type of portable band mill have been developed. If proved successful as a working mechanism, this mill may bring about an improved order in its field. Mechanically, it introduces changes in layout and operation which increase portability by 50 per cent, on the basis of weight-length factors. In farm forestry and forest community enterprise the need for this or some equivalent development is outstanding.

Marked economies have accrued to both producers and consumers through the use of dimension stock in lieu of "standard" lumber. The Laboratory's studies show definitely that small-dimension stock offers one of the most profitable forms into which low-grade and defective hardwoods can be converted. About 25 per cent of the hardwood material used by fabricating industries is now in this form; that is, cut at the source of supply to the exact sizes or multiples of the parts used in the assembled article. This development has had its roots in research on form of product, costs, methods and standards of manufacture, seasoning, grading, and packaging. Losses of 50 per cent in cutting up lumber at fabricating plants were found in studies of chair manufacture, and these are not unusual in furniture factories and other industries. Production of dimension stock is adapted to small-scale operation, as well as large, and to decentralization of manufacture and employment in the woods, as in the cooperative farm woodland management project at Cooperstown, N. Y., and the Tygart Valley cooperative at Elkins, W. Va. Such industries provide the modern counterpart of the old-time village planning mill, which in equivalent needs to be revived, if possible, in the interest of farm forestry.

The development of national standards for lumber grades, nomenclature, thickness, and moisture content in conformance with consumer needs, with which the Laboratory has been intimately concerned,

has made advances and suffered some recessions during the past decade. In the so-called "battle of the thirty-second," the various branches of the lumber trade came to grips with research findings in an attempt to put a stop to the skimping of yard lumber sizes. Although the official standards cannot yet be said to apply in individual transactions as widely as is to be desired, they remain as a rallying point for the better elements in the producing and building trades. Recent examination of some 600 houses under construction in typical cities throughout the East and Middle West disclosed that in the majority of cities the lumber used is up to standard in size, grade, and moisture content, but that in certain localities thin lumber and high moisture content are common. However, the Federal Housing Administration and leading lumber agencies, with the Laboratory aiding wherever possible, are making strong attempts to hold to the provisions of American Lumber Standards.

Grading standards for hardwood factory lumber involved intensive study for three years in efforts to work out practical means of minimizing waste in consuming factories and producing mills. As a result new grading rules have been officially adopted and are reported to be accepted by virtually all parties without dissent.

Southern hardwoods, growing under conditions conducive to wide variability between and within species, have long presented special utilization problems. Without better knowledge of these woods there is danger of further abandonment of forest land and unemployment of workers. Machining qualities, including planing, turning, and shaping characteristics, concerning which practically no systematic information was available, have been established by carefully controlled tests of 18 species. The research on planing, for example, has shown that freedom from machining defects is not so much a question of species as of the proper adjustment of cutting speeds and knife angles. Some of the less used "weed" species were found to rate high in turning qualities and in other properties.

The little-used species problem has its ramifications in almost every forested region. Research on the properties of such species and compensations for their weaknesses has been a major activity. Red gum, a little-used species of a quarter of a century ago, is one of the most useful species today. Artificial tyloses for red oak by a pore-plugging treatment was found to be as effective for tight cooperage as the natural tyloses of white oak. An intensive study of the properties and uses of aspen has helped this species to make distinct headway even in such exacting usage as Venetian blinds. As a result of similar information supplied to consumers and woodworkers, pecan and magnolia are rapidly gaining in use.

Even a brief sketch of accomplishments in a broad field from which virgin timber has practically disappeared can hardly fail to show that sawlogs, as the principal product of the forest, are not going to give over the future of wood usage entirely to new chemical and fibrous products. The prospects for widespread commodity forestry would be bad if this were the case. Pulpwood, of course, has an important place to fill. But improvements in harvesting methods and utilization practice are increasingly strengthening the commercial as well as the technical position of lumber among modern materials.

WOOD SEASONING AND MOISTURE CONTROL

By ROLF THELEN[1]

THE living tree, by a process never yet satisfactorily explained, is constantly conducting very considerable quantities of water from its roots to every branch and leaf. When this and other life processes are interrupted by conversion of the tree into lumber, much of the moisture remains in the wood. For most of the uses of man's devising, the wood must be dried until the moisture content reaches a norm which we refer to in general terms as dry or seasoned wood. Actually, the dried material should approximate the moisture environment which it will meet in service.

Because shrinkage is the natural concomitant of wood drying, it is necessary that the process be well finished before, and not after, the service period begins. Here the radical changes operating on the material may, unless safeguarded, cause disastrous effects of fissuring, surface checking, warping, crooking, or other distortion. If wood is too dry when fitted in place, it will reabsorb moisture and may suffer much damage through swelling pressure and deformation. Beyond the scope of seasoning operations, but nevertheless of increasing concern, are humidity conditions in houses which sometimes cause excessive moisture absorption or even decay of wood in walls and structural parts.

Thus the problem of proper moisture adjustment persists, in one form or another, from the beginning to the end of the useful life of wood. Faulty practices with reference to it have caused the loss of untold millions of dollars in lumber degrade and, through unsatisfactory service results, have paved the way for displacement of wood by substitutes on a wide front. The problem of moisture control presents to research a major challenge.

Improvement of kiln-drying methods was among the first and most urgent tasks of the Forest Products Laboratory. In the modern drive for speed and mechanization, the dry kiln was seen to be destined for increasing use in the seasoning of both hardwoods and softwoods. As a technical device it obviously invited definite adaptation of means to ends. Yet the kilns in use, or their ineffective operation, or both together, were producing all too frequent holocausts of waste and degrade instead of better-seasoned lumber.

To implement the study, suitable experimental drying equipment, unobtainable commercially, was built from original designs. The basic factors of kiln drying were analyzed and were found to be three: temperature, humidity, and air circulation. By proper time-control of these factors, it was found possible to meet all ordinary physical requirements of wood drying with minimum damage. A long course of experiments resulted in the formulation of practical kiln schedules for most of the commercially important wood species. Embodied in a handbook, the schedules are today in use at mills throughout the United States and in a number of foreign countries.

Kiln design and manufacture have also been fundamentally affected by the Laboratory's research. Among the earlier developments were the water-spray dry kiln and the superheated-steam kiln, both of which had an important measure of commercial success. Subsequently came the internal-fan kiln. Its operating principle, covered by non-royalty patents, is embodied in most of the dry kilns now made

[1]Forest Products Laboratory.

in this country and has won favor abroad as well.

More economical seasoning of lumber and better service to the user have been very general results of the work accomplished; the saving in material formerly wasted or badly damaged is reckoned in hundreds of millions of board feet each year. By no means, however, have all difficulties of kiln seasoning been removed. Certain wood species, notably swamp-grown hardwoods of the South and material of timber or "dimension" sizes generally, have never yet yielded to kiln seasoning with complete success.

Special research is now centered on these cases, with remarkably encouraging results from treatment of the wood with common salt or other chemical prior to drying. The method is based on the fact that various water-soluble chemicals have the property of reducing the water-vapor pressure of air in contact with their solutions, so that wood actually goes through a certain stage of drying while in the bath, without danger meanwhile of damage by checking or distortion. In the later stages of drying, and in service, a hygroscopic effect of the chemical holds the wood in satisfactory moisture equilibrium with its surroundings and further protects it from such damage; furthermore, shrinkage itself is considerably reduced. In addition to salt, the action of invert sugar has received intensive study because of its desirable electrical characteristics, and certain chemicals of marked potency in resisting shrinkage are under investigation at present.

Air seasoning, the traditional and time-tested method of drying lumber and timbers, is still in very common use. Depending mostly on the free agencies of nature, it is a cheap method that will doubtless never be superseded, and its possibilities and risks justify the continuing interest of research in its problems. In the post-war decade a broad cooperative study of air-drying principles was undertaken and rules for good practice were formulated. Major evils to be combated in air drying, besides deformations and checking of the stock, are decay and staining due to fungus attack.

Reduction of all these dangers to a minimum is found to depend on methods of piling the stock, on arrangement and management of the piles, and on proper care of drainage and other factors in the yard. Special measures are needed for particular species, as in the preliminary end-piling of sap gum. The findings have resulted in large improvements, but the pressing need is for their wider application rather than new research in this field.

Related investigations of storage conditions have shown that the benefits of good seasoning are often lost by careless exposure of lumber to untoward atmospheric conditions. In the case of temporary storage at the building site, it is found that various kinds of water-resistant building papers used as pile covers will give adequate and cheap protection. The effectiveness of open and closed storage sheds in keeping lumber dry has been determined. Several different systems of heating storage sheds for lumber that must be kept drier than is possible in unheated storage have been developed to the point of successful commercial application.

Suppose that a piece of lumber has been "properly" seasoned to suit its moisture environment in service. Suppose, too, that it has been carefully protected in its seasoned state and that a good carpenter has successfully nailed and fitted it into its appointed niche in a new house. What security is there that the moisture environment will be forthcoming that is "proper" to the seasoning of the lumber? In other words, what is "proper" seasoning?

To fix more clearly the standard which producers should meet in attempting to serve the user, this question was studied in the only way possible. Wood samples were placed in the various rooms of homes

in typical climatic regions of the United States. At stated intervals the samples were weighed *in situ* to determine how much moisture they had taken on or given off. Facts were thus determined which always before had been left to probability and conjecture.

Necessarily, an "average" interior humidity condition had to be calculated for rooms and homes in a given region, for the seasoning of wood is a wholesale operation. But as the result of the study it was possible for the first time to draw a "wood moisture" map of the United States, localizing three distinct gradations of moisture content in service. This knowledge, supplemented by a survey of the moisture content of lumber when shipped from mills and after delivery by rail, has better defined the objectives of "proper" seasoning and has afforded a basis for lumber associations in drafting new moisture specifications to embody in commercial grading rules.

Until recent years, both producers and purchasers lacked any quick means of measuring the moisture content of lumber, since the only accurate method involved complete drying and two weighings of samples or whole boards. This lack is now being corrected as a result of the Laboratory's research on electrical measurements. Both resistance and capacity effects were found available as a gauge of wood moisture, and instruments were constructed to demonstrate them. The principles developed have been followed in the United States and abroad in the production of moisture meters that give instantaneous readings and leave the wood practically intact. The method is meeting with wide commercial acceptance.

With the great increase that has recently occurred in air-conditioning, especially in homes, serious problems of moisture in concealed spaces have arisen. From numerous complaints it appeared that heat insulation of walls and roof, and similar improvements, were only increasing the trouble, frequently involving discoloration and peeling of paint, water dripping from attics, and spoiling of draperies and interior woodwork. The situation presented such a menace to advancing standards of home building, specifically with respect to wood construction, that a major research project was undertaken in the hope of finding a cure. Its cause was obviously the condensation of water vapor generated inside the house during cold weather, often with freezing followed by thawing.

The study, which is now in progress, offers technical problems of great interest. Special equipment has been provided for subjecting variously constructed, full-sized wall panels to indoor conditions on one side and "zero weather" on the other. A cabin has been built in which 55 different kinds of wall panels are undergoing exposure tests. The movement of moisture into the panels is constantly measured by electrical contacts, and with the aid of the data collected a clear picture is had of condensation as it progresses in various wall types. A finding that has already awakened nation-wide interest among architects, builders, and consumer groups is the efficacy of certain "moisture barriers" in keeping interior vapor away from cold recesses in walls and attics. The barrier may be asphalted or metallized paper or the like, placed just behind the lathing or ceiling board. Even interior paints of certain types have been found of help in preventing harmful moisture penetration and condensation.

The foregoing sketch indicates the progress of Laboratory research in response to a group of pressing and specific problems of moisture control. Fundamental matters such as the nature of the wood-water complex, the physics of moisture diffusion, and the stresses set up in drying are necessarily passed over. The continuing task of research is to strive toward the perfection of processes and practices through ever-clearer knowledge and adaptation of principles.

BROADENING THE BASIS OF AMERICA'S PULPWOOD SUPPLY

By C. E. CURRAN[1]

A CONDITION of unbalance has long existed in the United States' consumption of pulpwood, owing to the preeminence of spruce as a pulping species and the industry's early and continued fixation upon its use. As 20th-century demands for newsprint and other papers developed in full force, imports of foreign pulpwood, pulp, and even paper, generally products of spruce, increasingly supplemented a waning domestic supply of that species—until at present more than half of the Nation's pulp consumption is derived from foreign sources.

In 1936 the all-time record for consumption of pulpwood within the United States was broken by the use of 8,715,916 cords, which is more than a million cords above the consumption of any previous year. But amid all recent increases of demand, the significant fact emerges that the total quantity of spruce consumed for pulp has been less each year than that consumed in 1920. Some measure of the shift that is occurring is afforded by Census reports which show, by years, the various woods that have come into pulping use sufficiently to justify separate mention. In 1899, only spruce and poplar were listed. Ten years later, hemlock, southern yellow pine, balsam fir, and white fir had made their entry. By 1920 appeared yellow poplar, tamarack, southern gum, jack pine, and basswood; in 1928, chestnut, birch, beach, and maple; and at length, in 1932, poplar's poor relation, cottonwood. In addition, under "other woods," Census data now include Douglas fir, white pine, willow, cedar buckeye, oak, "miscellaneous species," and mill waste.

The technological scene is changing; and for a clearer understanding of what is happening, account must be taken of four distinct types of pulping processes. The "sulphite" process is at present the great common provider of pulps to be used, pure or in mixture, for making paper of many kinds and grades. It embodies acid cooking of the wood. A sheet of good typewriter paper fairly represents the quality of its bleached product. "Sulphate" pulping is an alkaline cooking process, well proved in the reduction of resinous woods; its typical representative thus far is the tough, heavy brown wrapping paper of the grocer and hardware merchant. The "soda" process is likewise alkaline; used commonly with hardwoods, its product is most often seen in books and blotting papers. The "groundwood" process, as its name implies, is the operation of grinding wood to pulp on a revolving stone. Its output, unbleached and with a reinforcement of sulphite, is the staple of today's newspapers and a flood of cheap magazines. Groundwood pulp is also used in large volume in fiber board.

Historically, the introduction of hemlock as a pulpwood rates high in importance. Eastern hemlock was first utilized in the Lake States as material for the sulphite process, and its use continues in volume —although, as compared to spruce, it is definitely inferior in respect to yield, color, and fiber quality. A higher standard is met by western hemlock, the use of which has lately grown by leaps and bounds. Though closely related to the eastern species, it is definitely superior in all pulping characteristics and is in most respects the equivalent of spruce for both sulphite and groundwork pulps. A somewhat dark color of the unbleached pulp is its main handicap, the elimination of

[1]Forest Products Laboratory.

which is a specific concern of research at the present time. Within the last ten years a large tonnage of bleached sulphite has been developed in the Pacific Northwest, and there have been moderate increases also in unbleached sulphite and mechanical pulps, all based on hemlock plus a small quantity of true firs.

By all means the most striking instance of changing practice in species utilization is the case of southern yellow pine. Its use by the sulphate process, beginning as early as 1909, had increased by 1929 to a volume of more than a million cords. In 1932, a depression year when other pulpwoods declined in use, southern pine registered a consumption of a million and a quarter cords. In 1936, more than two million cords were consumed, and with the further expansion of the industry that is now under way, a requirement of four million cords by 1940 is confidently expected. On a direct comparison with the current spruce requirement of some ten million cords from all sources, the importance of this development is apparent. It represents the operation of some forty mills, the addition of $200,000,000 to the South's industrial investment, an unpredictable increase of land values and farm income, and the productive employment of some 40,000 workers in woods and mills.

Other softwood species of current or potential prominence are balsam fir and the western true firs, jack pine, Douglas fir, tamarack, lodgepole pine, ponderosa pine, and certain cedars. Jack pine, tamarack, and Douglas fir now find use in kraft (sulphate) pulps, and jack pine also supplies a minor quota of sulphite and groundwood. Since it occurs plentifully in areas where, owing to formerly existing stands of spruce, a pulp industry has already been built up, jack pine offers a chance for the possible continuation of operations without removal of mills to new territory.

A distinct increase in the quantity of hardwoods used for pulping is shown by Census figures. By far the greater proportion of hardwoods falls to the share of the soda process, but in recent years considerable amounts have been pulped by other means. For instance, in 1929 some 13,000 cords of hardwoods were used for sulphite pulp and 15,000 cords for groundwork. In 1930 the quantity of hardwood used for sulphite pulp increased to approximately 66,000 cords and for mechanical pulp, to almost 38,000 cords—increases of 400 and 150 per cent respectively. This trend continues. Aspen (poplar) predominates in all instances, but, as noticed previously, such hardwoods as beech, birch, maple, black gum, willow, cottonwood, and even oak have all come into use.

These technological advances represent the combined efforts of many agencies and individual workers. No one person or laboratory is entirely responsible for any of the major trends which have developed with respect to wood species. The Forest Products Laboratory has had its share in the movement. It was early in the field and has made substantial contributions.

In its investigations the most extensive species-survey on record was accomplished, more than 90 woods having been examined and their pulping characteristics experimentally established. The more important species have been or are being investigated more fully.

Experiments initiated by the Forest Service in 1907 established the suitability of the sulphate process for the production of kraft wrapping and paperboard grades from southern yellow pines. Sulphite and mechanical pulps were also produced from them experimentally. A news release in 1909, reporting the production of a sulphite pulp from Virginia pine, attracted much interest because of the possible use of this species for newsprint. Groundwood pulps from pine, of newsprint quality, were made on a semi-commercial basis between 1911 and 1916.

The use of multiple-stage bleaching was investigated and was reported in 1920. Improved cooking methods and further improved bleaching with chlorine in multiple stages were found to be applicable in making strong white papers from southern pines, and this fact was publicly announced in 1927. Further investigations were made of sulphite, sulphate, and mechanical pulping of southern pines, including the experimental production of newsprint, book, bond, writing, greeseproof, wrapping, and other grades of paper. In line with Dr. C. H. Herty's suggestions, the possibilities of young slash pine for newsprint were evaluated in the years 1930 to 1932. But, contrary to his proposals envisioning a sulphite-containing newsprint, the Laboratory has advocated use of a semibleached sulphate pulp in order to eliminate as far as possible the "pitch" trouble in manufacture, since the alkaline sulphate liquors dissolve "pitch." Under such a procedure, selection of young trees or wood of light color and low resin content will be necessary only for the groundwood component of the furnish, and a better use balance will be established for pine of various ages and sizes.

Most recent in the southern pine studies has been a thorough evaluation of growth variables as they relate to pulping. Such elements as ratios of springwood and summerwood, heartwood, sapwood, compression fibers, and growth rate have marked influence on papermaking properties. Often, in fact, they are more important than species differences. Knowledge of their effects has thus established a basis for realizing the greatest pulp return from the pines, both in quality and quantity.

The possibilities of hardwood pulping have received careful attention. In experiments made several years ago, high percentages of both sulphite and groundwood pulps of hardwoods were utilized in producing newsprint paper, at costs found at that time to be about equal to that of standard newsprint. In 1928 black gum, in particular, was found to yield paper of excellent newsprint qualities. Birch, beech, maple, aspen, chestnut, and other hardwood species have likewise been employed in producing a varied array of mechanical, sulphite, and sulphate pulps and papers which show promise of wide application.

The history of pulping shows how profoundly the development of new processes has affected the trend of species utilization. The discovery of the sulphate process and its application to southern pine is only one example. Particular interest therefore attaches to the Laboratory's explorations in the process field. The "semichemical" process, a combination of cooking and mechanical reduction, was introduced in 1926 and has since substantially increased the use of chestnut and southern gum. A semisulphite and semikraft process have also been developed, both of which have found considerable use in industry. The improvement of bleaching methods has undoubtedly helped to increase the consumption of hemlock, and, as already pointed out, is tending in the same direction with the southern pines. Work toward the development of new, soluble bases for sulphite pulping will, if successful, unquestionably lead to more diversified use of all resinous species.

There are relatively large stands of potential pulpwood in remote areas of the United States, not now used at all, which may eventually play an important part in meeting paper requirements and which challenge determined attempts to develop their true value. The trend toward a broader utilization of species for pulp production, though slow in past years, is now positive and is accelerating. The influence of research should be constantly at work to support economic moves in that direction, in order that our forest lands and forest resources may give a fuller measure of service and livelihood to the American people.

EXPLORING THE LABYRINTH OF CELLULOSE AND LIGNIN

By E. C. SHERRARD[1]

WOOD comes as a finished product of nature to the hand of the builder and the craftsman. To the chemist, however, wood is no more a finished product than is a slab of coal or a field of flax. It is raw plant tissue of a specialized type; its true usefulness can be determined only by a thorough discovery of its inward structure and substance. In the domain of physical and organic chemistry lie possibilities not only of converting wood into manifold new products of value, but also of adapting it more and more adequately to requirements of established use.

Wood is a definite entity; it is substantially alike in trees of all species. Its chemical make-up, however, is not simple. To say that it consists of the elements carbon, hydrogen, oxygen, and none other is a truth leading nowhere in particular; the same analysis would hold for sugar, carbolic acid, or pine rosin. Even to measure C, H, and O by quantitative methods reveals no property of wood except as a fuel. To capture its concealed values requires a far more subtle approach.

Wood is a mixture. Experimentation a century ago accomplished its separation into two main components—a fibrous, cotton-like part comprising the cell bodies proper and designated as *cellulose*, and a part denominated *lignin*, the essentially "woody" component, appearing chiefly as an encrusting or compacting medium between the cells. There also exist in wood, in some associative pattern, a considerable group of intermediate compounds, designated in general as *hemicelluloses*.

Furthermore, wood is a labyrinth. It consists of parts within parts. Methods of microchemistry, recently developed, have thrown light on its inner recesses. The lignin complex has been isolated as a continuous web or honeycomb, with traces of interpenetration into the fiber walls. The fiber, a hollow body of about the size of a hair removed in shaving, has been examined throughout its range of visible structure. About it is coiled a cellulose filament of marvellous fineness, binding its parts together. Within, it is found to consist of three or more concentric layers of cellulose, each a compact of some hundreds of parallel fibrils having a slight slope or twist about the fiber axis. Composing the fibrils are still smaller spindle-shaped integers, named *fusiform bodies*. These, in turn, are made up of ultimate microscopic objects, units of cellulose so minute that their relation to the whole fiber is as a golf ball alongside the Washington monument.

Taking up the search where the microscope must leave off, instrumentalities such as the ultracentrifuge and the X-ray are yielding information on the molecular dimensions and character of both cellulose and lignin. Closely related studies are exploring the maze of capillary and submicroscopic water-conducting passages throughout wood. Their fineness and manifold complexity are witnessed by the finding that, within a single cubic inch, the internal wood surface bounding them is more than 50,000 square feet.

The scientific concept thus obtained of the wood aggregate and its subdivisions, though still far from complete, has bearings on present technical problems and far-reaching implications for the future. For example, recognition that lignin forms an enveloping matrix about the fibers le

[1]Forest Products Laboratory.

to the development of the "semichemical" pulping process, the story of which, with its high yields and its successful adoption in industry, is told in another section. Structural analysis of the cellulose fiber has made clear to the papermaker the degree to which fibrillation of a pulp, produced by beating, affects the strength of paper. It has also, for the first time, given the rayon manufacturer a knowledge of the various microscopic units through which the fiber passes during dispersion of cellulose prior to its emergence through the spinnerette. In the drying of wood, successful results depend on the proper removal of water from its minute structure by diffusion after the larger cell interiors are empty. Increasing knowledge of the structure in which diffusion takes place aids in setting up efficient drying conditions, either by temperature and humidity control or by the new method of chemical seasoning elsewhere described.

To the general user, the one greatest drawback to wood in service has been its tendency to shrink or swell as its moisture environment changes. Successful antishrink treatments were unknown until, in the course of research, it was realized that moisture-excluding agents must be used which will bond with the innermost parts of the wood substance. By a new "substitution" method of impregnation with synthetic resins, the swelling and shrinking of wood can now be reduced to about one-quarter of that naturally occurring. The process is applicable to superior manufactured articles such as shoe lasts, athletic goods, brush backs, lithograph blocking, and musical instruments, and studies are now under way looking to its use in the production of a permanently weatherproofed plywood for house construction. In these and related fields of wood research—preservative treatment, painting, gluing, decay investigations, and the rest—the facts of wood's minute structure supply the necessary groundwork of both sound theory and improved processes.

Cellulose fiber is the acknowledged treasure of the wood labyrinth. For decades chemists have found its investigation exciting and rewarding, until today the world stands fascinated with the profusion of its products—papers of every variety, boxes, cartons, and fancy wrappings, rich fabrics, pressed and molded articles, photographic and projection films, lacquers brilliant of hue and surface. To this great development the Forest Products Laboratory has contributed its part by clarifying ideas as to what constitutes the cellulose part of wood and by devising means of recovering more of it in useful form.

According to common analytical procedure, wood is considered to contain about 60 per cent of cellulose. A new concept, however, has arisen with the introduction of a less severe method, by which wood is found to yield a total carbohydrate fraction of 77 per cent. Signifying its cellulosic character, the carbohydrate component has been given the name *holocellulose*. Not only does holocellulose contain substances formerly disintegrated, but its content of superior fiber, the tough alpha-cellulose of fine paper and rayon, is considerably higher than has been obtained before, either analytically or commercially. This fact points to the possibility of new and radically different pulping processes, with higher yields and less waste.

The setting up of the new body, holocellulose, has found an incidental application outside the field of forest products. Researchers in animal nutrition have wanted to find out to what extent lignin interfered with the assimilation of plant carbohydrates, but have never been able to remove the lignin without also removing part of the carbohydrates. Holocellulose, the total carbohydrate group, lignin free, was the answer to their problem.

In the recovery of pulps with high

yields, the so-called hemicelluloses will play a major or minor part, according to the degree of refinement required in the final product. On the other hand, their part in hydrolytic reactions for purposes such as ethyl alcohol production is exceedingly interesting, as many of them are readily convertible into sugars. While their structure and relationships in the wood complex are not as yet fully determined, current studies indicate the close association of at least a part of them with the lignin fraction. The acetyl and certain of the methoxyl groups, however, which yield acetic acid and methyl alcohol, have been shown to be chemically attached to the cellulose.

If cellulose is the treasure of wood, lignin as hitherto regarded has been mere slag or offscouring—dross to be purged in the winning of fiber; and it pours out from pulp mills at the rate of a million and a half tons a year, to pollute rivers and perplex the public and conservation authorities. Yet lignin, comprising one-quarter of the wood substance, was put together by nature for a definite function. It must have definite chemical characteristics, and perhaps, were these fully known and determined, products might be developed from it as useful as those now extracted from packing-house wastes or from that once valueless refuse, coal tar.

Such was the conception with which the current research on lignin was undertaken. The chemical problem has proved as hard as its past history would lead one to expect. Lignin is a stubborn material, ambiguous in its reactions and grudging of any clues to its composition or hidden values. A limited disposal of lignin-bearing pulping waste is found in the manufacture of linoleum adhesive and in tanning operations, and its use as a road binder or a component of fertilizers offers some promise; but for lignin itself, the utilization program awaits a fuller revelation of what it is.

The unknown is at last taking shape. Paralleling the holocellulose separation, lignin is now segregated as a thing in itself free of all cellulose-degradation products. Considerable differences between typical hardwood and softwood have been distinguished. Five hydroxyl groups have been identified as a part of lignin, one of them being a secondary alcohol and another an enolic compound that can condense with phenols to form resins. Five methoxyl groups have likewise been identified, one of which on distillation of wood yields methyl alcohol. Another finding, which departs radically from former conceptions, is the disclosure by X-rays that lignin has a definite crystalline structure; all previous conclusions were that it was amorphous in character.

Research has lately been reinforced with the powerful aid of the hydrogenation process, the transformation by which gasoline is generated from coal, and cooking fats from vegetable oils. Under hydrogenation, lignin can be converted completely into glycols, alcohols, and a residue similar to a high-grade synthetic resin. One of the alcohols produced is propyl-cyclohexanol, a liquid of pleasant odor suitable for use as a lacquer vehicle. It is also inhibitory to wood-destroying fungi and hence gives promise as a wood preservative. Of the two glycols, one is a waxy crystal and the other a viscous liquid adapted for use as a thickening and toughening agent for varnish.

These various developments are only parts of a chemical picture which remains to be completed. But they are already opening up vistas into an economic future for lignin. A fortunate outgrowth of the research has been a vast improvement in the performance of millions of automobile batteries. No sooner had lignin been isolated in pure form than manufacturers began incorporating it as a part of negative battery plates, with a tenfold increase of current output in zero weather.

At an early stage of the lignin research it was noted that formaldehyde had a pronounced softening effect on the material, and that upon drying a hard, resinous product was obtained. This observation led directly to the development of a process for the production of a new type of molding compound. Its formation depends on the removal of part of the cellulose from wood by cooking with dilute acid, with consequent increase of the lignin content of the residue. The softening point of the lignin is lowered by the addition of plasticizers such as aniline and furfural, so that the mixture can be hot-pressed at 3,000 pounds per square inch to form a hard, dense, brilliant black molded product of low cost. A number of industries are interested in it, and its possibilities in the production of plastics from wood waste, especially sheet materials, panels, and wall boards, are very apparent.

Such, in outline, is the account of the Laboratory's exploration of the wood labyrinth to date. Facts of scientific and practical value are being brought to light, and the boundaries of the unknown are being pushed back a step at a time. The search goes hand in hand with efforts of other workers, and by this cooperative attack the time is being hastened when the inner wealth of wood will be fully at the command of society.

TREATING WOOD FOR PROTECTION AND SERVICE

By GEORGE M. HUNT[1]

WOOD, as a raw material, generally requires less special treatment to fit it for service than most other raw materials. But a certain degree of preparation to enhance its qualities and prolong its usefulness is essential. This has long been recognized. The practice of painting wood, for example, arose before the dawn of history; likewise the gluing of wood, and the "pitching" of ships' planking.

In the modern era, there is double reason for carrying on such practices with care and skill. Not only is an exacting public to be served, but, for every failure in wood's performance, technology is ready to press the claims of other materials that will meet requirements more closely, if not more cheaply. The service life of wood must be better safeguarded against both natural enemies and man-made hazards. Processes by which wood is prepared for special types of use must be developed and improved. In all this the active aid of research is needed. Investigations of the many kinds of treatments and applications required fall for the most part into four well defined fields: Preservative treatment; painting and finishing; fire-protective treatments; and gluing and related processes.

Decay, the greatest destroyer of timber in use, is ably assisted by insects and marine boring organisms. Thorough preservative treatment and proper precautions in construction are needed to thwart these harmful agencies. The degree of success attained in treatments gives wood today a strong position as an economical material for railway ties, poles, piling, and other outdoor timbering. Without such protection the movement toward concrete and metal for all kinds of structures subject to decay and insect damage would be greatly accelerated. There is still need for great improvement in preservatives

[1]Forest Products Laboratory.

and preservative methods, in order to increase their effectiveness, reduce the cost of wood per year of service, and make treated wood more generally available.

Various degrees of treatment are involved, depending upon the intended use —the heaviest treatments, with creosote, being required for piling in teredo-infested waters. Vast quantities of wood are wasted through insufficient penetration. Investigations of the effect of temperature and pressure in a thoroughgoing series of experimental treatments have shown how to gain better penetration by using moderate pressures with relatively high temperatures, thus obtaining higher mobility of the preservative liquid. As an important outgrowth of the temperature studies, new heat-conduction formulas for wood have been derived, placing the preheating stage of the preservative process on a basis of accurate control for the first time and removing it from the costly empiricism of the past.

A constant stream of new preservatives, of varying degrees of excellence, seek outlets among the consuming public. Some of these are offered for use by standard pressure-impregnation methods. Most, however, are recommended for surface or "brush" treatments. Despite many attempts to devise a quick test for judging preservative efficiency, the old method of service records, even though time-consuming, remains the only reliable one. Some 50,000 test specimens in great variety of size, character, treatment, and geographical placement, are at present under observation for the compilation of such records on a great number of preservatives. Meanwhile studies of the chemical principles of toxicity and tests with many species of wood-destroying fungi are laying groundwork for the development of new preservatives as a scientific undertaking rather than a promotional coup.

The one timber item most in need of preservative treatment today is farm fence posts, of which the number replaced each year by reason of decay is in the neighborhood of 400 million. Effective home treating methods hitherto offered have not found wide acceptance, and commercial treatments are beyond the reach of the majority of farmers. The most promising recent development in simplifying and cheapening fence post treatment is an adaptation of the Boucherie process, by which green, round, unpeeled posts of low decay-resistance can be made as durable as cedar at a cash outlay of 5 to 10 cents per post. The treating chemical is zinc chloride and the means of application is a used tire-tube stretched over the end of the post. The advantages of the method are obvious. Experiments with posts of a number of species are under way, and results thus far encourage the hope that post treatments by the tire-tube method may soon become common practice.

Red will no longer be the dominant color note of the American barn of the future, if research disclosures in regard to paint durability make their full impact. Exposure tests made throughout the country have proved that on all commercial lumber species the longest service and best all-around protection against weathering is rendered by paint in which the pigment is flake aluminum. The silvery luster of such paint will probably work against its acceptance for the complete painting of houses, but as a priming coat its use will often prove of distinct advantage.

This finding is one result of a broad investigation of wood painting, having as its practical objective a reduction of the consumer's paint bill, which now amounts to some half a billion dollars a year. Causes of paint blistering, cracking, peeling, and discoloration have been analyzed, means of avoiding abnormally early paint failures pointed out, and the paint-holding characteristics of different woods determined. It is in respect to its lasting quality on the more difficult type of woods

that aluminum paint has been found outstanding.

The role of moisture in walls as an enemy of paint has been discovered, accounting as it does for many paint troubles. The remedy in such cases lies not with the paint but with effective means to prevent moisture accumulation—although pure white lead is more resistant to moisture blistering than mixed pigments. An unsuspected factor of incompatibility has been found to lie in the chemical make-up of different paint pigments, so that certain sequences of coatings in repainting are now known to be safe, and others doomed to failure. Even for the owner who is deliberately neglectful of repainting, research gives information of value, for a coating of white lead or, in some climates, white lead and zinc oxide, is found to retain some of its appearance value long after its other surfacing qualities have given out.

It is believed that a revolutionary improvement in painting practice and paint purchasing can be brought about by a system of paint classification and grading roughly analogous to lumber grading and species selection. With this objective in view, a tentative system has been devised and is now being urged upon a reluctant industry for improvement and adoption. Ready-mixed-paint formulas are constantly changing and varying over a wide range in character and quality. The purchaser is generally at a loss to tell good paint from poor. Specific recommendations for the use of mixed-pigment prepared paints are almost impossible as long as the present confusion is allowed to continue, and a major effort on the part of paint technologists is needed to remedy this situation.

Wood is by nature a combustible substance, and efforts to make it "fireproof" in the sense that brick and stone are fireproof are beside the mark. Objectives in this regard must be confined to reducing fire hazards in construction and treating wood with materials that will reduce the speed of burning and check the spread of flame. By such means the danger of fire from causes both internal and external to the house can be held to a practical minimum, so that no just grievance can be brought against wood except for situations of extreme fire risk.

Of 150 chemical compounds and mixtures thus far tested as impregnating materials, those involving ammonium phosphate, ammonium sulphate, borax, and boric acid were found best. All require high absorptions of chemical for their full effect, and for that reason cannot be considered cheap. Resistance to decay, insects, and leaching can be combined with fire resistance, but these advantages, too, are gained at considerable cost. In the course of the investigations a yardstick of the effectiveness of a treatment was devised and has since been widely adopted, both in the United States and abroad. This is the fire-tube test, by which the loss of weight of a standard specimen is measured during the actual course of combustion.

Many fires originate from cigarette butts, burning match stems, and other small sources. To prevent fires growing from such beginnings is half of the battle in reducing fire losses. Coatings that can be applied to the surface with brush or spray gun, in contrast to impregnation treatments, offer promise in retarding the spread of fire. While no coating can yet be recommended for general use, research in this field is being actively prosecuted in the hope of developing a coating or coatings that can be used effectively and economically to prevent rapid spread of fire in walls and basements, and can be applied by the home owner in old or new structures.

In general estimation, plywood would never rate as a "fireproof" material. Yet it has been found that if the new phenolic resin glues are used in the making, a considerable factor of fire resistance is ob-

tained—far more than when animal, casein, or vegetable glues are used. Plywood panels 1.7 inches thick, glued with phenolic resin adhesive and exposed to flame according to underwriters' standards, resisted burning through for a whole hour.

The constant improvement of glues and gluing is a vital part of wood utilization research. Glue for centuries has been a stout companion to wood in meeting difficult requirements of fabrication. By contributing to smoothness and strength of joining, it has multiplied the serviceability of wood in the hands of the craftsman. As new demands devolve on wood, the demands on glue become all the more urgent. Better gluing gives better plywood for more exacting uses. Control of gluing technique makes for dependable veneered products and supplies the average home with better, stronger, and more attractive furniture. Water-resistant glues make possible built-up and laminated construction in broad new fields of service—in building, in transportation, in aeronautics. To an unpredictable degree, the future of wood lies with scientific developments in gluing.

The Laboratory's first major studies in this field resulted in the discovery of basic principles of good gluing with starch, animal, casein, and blood glues—findings which for the first time made gluing a sound technology instead of the mysterious rule-of-thumb practice it had been for ages. Other results were determination of the gluing properties of more than 40 species of wood, the development of new and better low-cost casein and blood glues, and the formulation of the first reliable methods for testing the strength, water resistance, and durability of glue joints. Hot-press resin glues of outstanding moisture resistance are now available in increasing numbers, and studies are proceeding in the special techniques involved in their use. Some of these glues are found to retain a large percentage of their original strength over several years of severe exposure to alternate wetting and drying. Their performance in this respect is far superior to that of any of the older types. An economical cold-press glue having the high strength and water resistance of the hot-press resin glues would be a further help in woodworking, by permitting the gluing of larger and thicker material. Such a glue may be developed through research that is now in progress at industrial establishments. The Laboratory's studies at present are centered on determination of maximum durability and strength obtainable from the resin glues and on setting up minimum performance requirements. Large-scale outdoor tests are under way to determine the durability of the glue joints, the extent to which the face veneers resist checking, and the protective value of various surface finishes. These tests supplement thousands of small-scale accelerated laboratory tests.

Experience in the testing of glued veneers and plywood indicates that products of superior quality are the result of both good gluing and good cutting of the unit plies. No thoroughgoing study of the veneer cutting process in all its phases has yet been made. Research in that field is contemplated, with the use of equipment now available. The work in view involves determination of methods for preparing the logs, optimum conditions for producing quality veneers from woods of different species, and methods for reducing waste in cutting. With all possible underlying facts developed to guide the production of veneer, its gluing into composite forms, and the testing of the products for strength and serviceability, together with steady prosecution of research in general gluing practice, painting, and protective treatments, wood will be the better prepared for effective performance in fields of utilization both old and strictly modern.

THE NATION-WIDE FOREST SURVEY

By RAYMOND D. GARVER[1]

UP TO the beginning of the twentieth century, while the legend persisted that the forest resources of this country were "inexhaustible," there was little concern about the available supply, the rate of depletion by logging, disease, insects, and fire, or the replenishing of these losses by growth. In the first decade of the new century a suspicion that all was not well grew speedily into a state of alarm, the cry of "Timber famine!" was raised, and public opinion, as little informed about the actual facts as before, was swept somewhat violently in the opposite direction.

Gradually, however, as legend faded and alarm proved not wholly justified, it became increasingly apparent that actual facts regarding the condition of our forest resources were conspicuously lacking. We had, so to speak, a vast warehouse from which stocks of goods were being poured out and in which other stocks were accumulating, but with no satisfactory record of the rate of outgo or of replenishment. There was no real knowledge, with respect to forest resources, whether the country was headed for comfort and security or gradual or precipitate want. Ten years ago, however, under the authorization of the McSweeney-McNary Act, the federal government embarked for the first time on an adequate inventory, known as the Forest Survey, in the attempt to balance its forest bookkeeping.

The Survey seeks to determine for all parts of the United States, (1) the extent, location, and condition of forest lands, and the quantity, kinds, quality, and availability of their standing timber; (2) the rate of forest depletion through cutting, fire, insects, disease, and other causes; (3) the current and probable future rate of timber growth, and the productive capacity of the forest land; (4) the present and probable future requirements for forest products, by all classes of consumers; and (5) the relationship of these findings to one another and to other economic factors involved in forest land utilization.

This information is essential to guide the course of forestry and to synthesize forestry with other major types of land use. The swelling demand for Survey data in those parts of the country where field work is measurably complete has come from many federal agencies, from state agencies, and from public utilities, railroads, and particularly the great forest industries themselves.

When an investigation, only half completed, is seriously slowed down by the job of answering inquiries for the information so far obtained, there is little reason to state the need for undertaking it, or for completing it in the shortest possible time. In terms of information furnished and services rendered, the Survey is already paying for itself.

Previous to 1930, when field work was begun, there had been timber surveys on the national forests, and an occasional state inventory such as that made in Maryland, but in no case such a thoroughgoing analysis of the forest resource on a nation-wide scale had ever been attempted in the United States. A new technic had to be formulated in which specialists took an active part. Every angle of this technic was given critical analysis and was subjected to field trial and tests for statistical sufficiency before final approval. Space is lacking to give any of the details of a

[1]Forest Survey, U. S. Forest Service, Washington, D. C.

job which, although involving endless drudgery, has at times been not untouched by romance.

The results begin to answer many questions. Our present and prospective forest products needs, for example, are indicated in the lumber consumption trends as shown, in millions of board feet, in Table 1.

The decline of lumber used in farm construction is explained by the passing of the expansion era in agriculture. Annual maintenance over long periods is now estimated at 1,000 board feet per farm, or for all farms about 6½ billion feet.

In spite of much talk of substitutes, lumber is still the predominating building material for residential construction but must fight to hold its own. It is estimated that 450,000 new living units will be needed annually between 1930 and 1950 to house the increase in population. This compares strikingly with the 720,000 units built annually from 1920 to 1930. Average lumber per living unit has dropped from 17,400 board feet a generation ago to 14,200 board feet. This drop is explained by masonry and fireproof construction of multi-family houses. Such construction, and prefabrication, now threaten lumber in the low cost field, where it should be most secure. Experience in other industries warns that mass production invariably leads to the use of materials that can be poured, pressed to shape, or stamped out; this puts wood at some disadvantage, which may be overcome by developing methods of prefabrication.

Lumber in "other construction" has apparently reached a fairly stable position, and consumption now varies with the volume of general construction. Factory consumption of lumber follows the trend of the business cycle. Lumber is expected to hold its own for certain uses, as for example in railroad car construction and in furniture, but for other uses, such as motor vehicles and refrigerators, it will probably lose further ground.

Abundance and cheapness are extremely important in maintaining the competitive position of forest products in the industrial field. For example, the use of petroleum distillates by the paint industry as a substitute for turpentine grew out of an anticipated shortage of naval stores envisaged 30 years ago but never realized. Control of the acetic acid and methanol markets by synthetic products is the result of price competition and unavailability of suitable wood products during the World War emergency. The steel beer barrel gained a foothold immediately after the repeal of the 18th Amendment when seasoned white oak staves were hard to get.

Thus far the forest inventory phase of the Survey is well along in the South, the Pacific Northwest, and the Lake States. Some of the outstanding facts on the forest situation for about 213 million acres of land stretching from South Carolina to Texas are of interest: Fifty-nine per cent

TABLE 1

LUMBER CONSUMPTION TRENDS, IN MILLIONS OF BOARD FEET

	1909	1928	1932	1936	Probable average 1937-46
Farm construction	12,000	6,300	2,100	7,000	7,500
Residential (non-farm) construction	10,000	12,000	1,500	5,200	9,000
Other construction	9,000	7,800	3,300	5,700	6,200
Factory	12,000	10,300	4,600	6,100	7,300
	43,000	36,400	11,500	24,000	30,000

or 125 million acres, is in some stage of forest growth; on the average it is about one-third stocked. An additional 4 million acres of abandoned farm land are about to revert to forest. Only 18 million acres bear a substantial amount of old growth; of this 11 million acres have been culled. Seventy-eight per cent of the forested area, or 97 million acres, is in second-growth timber, of which one-half has reached sawtimber size. Hardwood species occur in significant quantities on 65 million acres, and make up 44 per cent of the total sawtimber volume. There are 10 million acres, mostly in the naval stores region, of hopelessly denuded land.

Evidently the description of the South as the land of cotton, sweet potatoes, and peanuts is not altogether complete. Perhaps forests should head the list. Every state in the region has more land in forests than all other uses combined. Florida leads with 74 per cent forest land, and Mississippi trails with 54 per cent. In 1935 there were still 264 billion feet of sawtimber in the lower South—147 billion feet of pine and 117 billion feet of hardwoods. In addition there were 454 million cords of wood in trees below sawtimber size.

Because the main sawtimber and pulpwood supply is in second-growth stands, second growth merits special attention. There are nearly a hundred million acres of it. Much of this vast acreage, however, supports less than half a normal stand of trees. Very little is fully stocked. Besides being poorly stocked, many second-growth stands contain a fairly large proportion of trees of low quality for timbers or sawlogs—trees stunted, rotted, or crippled by turpentining. Clean-up and profitable utilization of these stands by sawmills and the recently expanded pulp industry of the South, working together instead of in competition, depends partly on how rapidly new growth supplies more promising timber.

Growth of a cord per acre per year is often claimed for pine. This is possible, and if attained region-wide would supply ample wood for present needs without close integration of industrial management. But Survey computations indicate that this growth is not taking place. They show an average of 0.2 cord per acre per year in the naval stores region, 0.4 cord in the Mississippi Delta hardwoods, and 0.5 cord in the remainder of the lower southern pine region, both east and west of the Mississippi River.

How do increment and drain compare? Considering all sizes of timber 5 inches and larger, in cubic feet, growth is slightly in excess of drain. Sawtimber sizes of both pine and hardwood are, however, being cut faster than they are being replaced by growth. The sawtimber ratio of drain to growth in board feet for the lower South was determined as 1.1 to 1.0 in 1935. If all trees 5 inches and larger are included, the ratio in cubic feet is 0.9 to 1.0.

These figures, however, are of only general interest. They can be misleading—especially so where quality increment is important. To be wholly usable, such information must be amplified by an analysis of accompanying forest conditions and a showing of expected growth by size classes. Above all, supply, growth, and drain must be related to smaller areas, such as groups of counties, parts of states, and states. Such an analysis is now in course of preparation.

The present serious understocking of all large forest areas, disclosed by the Survey, offers an opportunity for employing labor on a large scale in rehabilitation. For example, as many men as are required to farm 100,000 acres of cotton could be employed by a large southern pulp mill, if to the jobs involved in woods and plant operation were added stand improvement work on the timber lands to support the mill.

In 1936 Washington and Oregon ranked first and second, respectively, in lumber

production, and supplied 36 per cent of the nation's lumber. Of their cut, Douglas fir from west of the Cascades made up 70 per cent. Lumbering on a small scale was in progress in the Douglas fir region nearly a century ago. With the completion of the Northern Pacific Railroad in the eighties, and the lowering of freight rates on eastern lumber shipments in the nineties, lumber from this region became a real factor in the national market. Will it continue? The Forest Survey in the Douglas fir belt shows that of the four-fifths of the total land area that is in forest, 56 per cent is privately owned and 44 per cent publicly owned. Probably one-third of the total sawtimber in the United States, or 628 billion board feet (mainly Douglas fir), is here. Stands average about 3/5 fully stocked. Old non-restocked cutovers, recent cutovers, and deforested burns total 4.4 million acres. Annual drain from all causes is estimated at 9.4 billion board feet, or only 1.5 per cent of the resource. Current annual growth is computed at 2.7 billion board feet. Under good forest practice it could be 6 billion. For sawtimber, drain is approximately four times current growth. In one way, the last statement is not necessarily alarming because of the extensive stands of mature non-growing timber. What arouses apprehension is the concentration of logging in easily accessible areas, resulting in overcutting the timber surrounding dependent communities, and the inadequacy of present restocking of cut-over land.

Forest products from this region will undoubtedly come into the lumber and timber markets in competition with those of other regions for many years, if not indefinitely. Much depends, however, on the proportion of the timber which is economically operable, as time goes on, and the extent to which partial cutting replaces clear cutting, and trucks and tractors high-lead railroad logging.

The relatively low current annual growth is partly due to the high proportion of old-growth timber, in which natural drain approximately offsets growth. A light partial cutting in many old-growth stands would utilize much of the timber now lost through mortality, place them in condition to put on net growth, and permit a continuing cut of high quality material at short intervals.

The Job Ahead

The end of the Forest Survey as a nation-wide undertaking is not in sight. Analysis of the information for 289 million acres of forest land already examined is only half completed. Determination of the present and future requirements for timber and other forest products must be finished. California, the Southern Rocky Mountains, part of the Inland Empire, the Ohio Valley, and the entire Northeast remain to be covered and reported on. After the completion of the field and office work, region by region and for the nation, will come the job of keeping the Forest Survey findings up to date. This is necessary to provide a means of periodically balancing the national and local timber budgets. Both office and field work will be required, but on a small scale as compared with the original job.

Sound natural resource management, whether it concerns our priceless soil, our waters, our minerals, or our forests, must rest on a firm foundation of authoritative information. The Forest Survey is designed to provide this foundation for forests and forest land, and to clarify the principles of permanent forest land use. It is basic to sound forest policy and programs, regional and national.

HIGHER ECONOMIC AND SOCIAL RETURNS FROM FOREST MANAGEMENT

By B. P. KIRKLAND[1]

MORE than 300 years ago, American lumbermen began their long quest for timber profitable to cut at once or to hold for future cutting. This search was to extend from the Atlantic to the Pacific and from the Great Lakes to the Gulf of Mexico. Only a handful of them—and these the profession of forestry salutes—looked within their own forest properties both for trees profitable to cut at once and for trees to provide future cuts. Now men know that by combining intelligent selection of trees to cut currently and of trees to reserve from cutting, with resolute limitation of the volume cut to about the annual or periodic growth, management can yield more sure returns than did the speculative operations of bygone days. These results are obtainable by basing cutting operations on the values (for cutting or holding) of individual trees or classes of trees rather than on average values in the whole stand.

To the late W. W. Ashe should be credited the start, as early as 1913, of the first systematic studies of individual tree values in the country. It was not until research was formally organized as a major undertaking of the Forest Service, however, and particularly until expenditures for economic research were authorized by the McSweeney-McNary Act, that these studies could be extended to most of the principal forest types of the United States. The Forest Products Laboratory and several forest experiment stations participated in this work, and have besides made considerable progress in correlating the findings of these studies with growth of individual trees and diameter classes and with silvicultural practices. Much remains to be done and many refinements of procedure are necessary before results can reach maximum utility.

The conclusions so far reached can be better understood by giving a concrete example. Because of their simplicity and compactness, data obtained by the Southern Forest Experiment Station in the shortleaf and loblolly pine type are chosen. These data, precise within narrow limits for the conditions where and for the time (1936-37) when they were gathered, have many broad implications, only a few of which can be discussed here. The figures are given in Table 1.

The data under each diameter class in the table represent averages for all merchantable trees in the class. It is, however, readily observable in the woods that the trees in each class vary in merchantable quality. A technician of moderate silvicultural skill can also readily distinguish healthy, fast-growing trees from diseased, insect-infested, or slow-growing trees. Merchantable quality and silvicultural condition, correlated with tree value, constitute the two bases for frequent light cuttings designed to remove trees that have culminated in value or slowed down in value increase, and to reserve for further growth those of high quality and vigor. This process of gradual improvement applies with minor variation not only to the many-aged forest, which it maintains in that condition, but also to the forest even-aged by groups, or even-aged over large areas. If an even-aged stand is opened by cutting of individual trees or groups, regeneration usually appears in

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some parts of the stand ahead of others, and after repeated cuttings the stand will become uneven-aged, also by groups or individual trees. The term "selective timber management" has been used to cover these selective measures in all types of stands.

From Section B of Table 1 it can be seen that pulpwood utilization alone, at existing low values, gives lower returns than saw-timber for diameters above 14 inches. On the other hand, integrated utilization of pulpwood and saw-timber (see Section D) will increase the returns if pulpwood cutting is confined mainly to thinnings in the pole-timber sizes and to salvage. For good second-growth southern pine this divides the yield in proportions of about 40 per cent pulpwood and 60 per cent saw logs. Wherever pulp or other cordwood-using industries exist and their demands are thus met from the by-products of saw timber production, the foundations for the most profitable management are present.

To sum up, these studies are providing the precise knowledge of economic returns from different forms of utilization on which regimes of light and frequent cuttings may be operated. With merchantability for various purposes precisely defined, mortality losses in merchantable trees may be reduced to a minimum by early identification and removal of insect- or fungus-infested, or other surplus trees; trees of slowing growth may be removed before they cease to earn adequate returns; slash from a single cut may be kept at a minimum; and if annual cut is somewhat less than growth, the growing stock, particularly in the larger sizes, may be built up at low cost. Studies now under way will make it possible to prescribe quite definitely the composition and character of the permanent growing stock to be sought as ideal for forests under this management regime. Motorized machinery also is helping greatly to facilitate this type of management.

The industrial significance of these data and their bearing on methods of forest management are noteworthy. Plywood and many other wood-using industries cannot exist, or at least cannot thrive, without continuing supplies of high-grade timber, which nearly always come from larger trees. These uses of high-grade materials are often closely associated with uses of lower-grade lumber which will decline if the better grades are not available. Building construction is a case in point. Any system of forest management that does not continue production of valuable large logs as well as smaller timber must therefore lead to the decline of wood-using industries as a whole. Cost data show that large timber invariably means the lowest utilization costs.

The social implications of effective management practices disclosed by these studies can hardly be over-emphasized. The saw-timber data of Table 1, Section A, were obtained where wages were 25 to 40 cents an hour, probably about the highest of the southern pine region. The labor was highly efficient and there is considerable doubt whether any other wage system or any other wage level would have brought forth greater efforts. There remains only a small margin for improving instruments and methods of production. It is, therefore, worthy of note that if Pacific Coast wage rates were applied in these operations, trees under about 20 inches in diameter and forests lacking a considerable volume of larger trees could not profitably be cut for saw-timber unless price levels should greatly increase.

Most of the labor engaged in pulpwood production, reported in Section B of Table 1, received remuneration equivalent to wages of 8 to 15 cents an hour. Wage rates as high as those in the saw-timber operation would probably reduce net conversion values (see Section D) to about 1 cent a cubic foot. In normal times there appears to be room for sufficient increase in pulpwood prices to permit paying

TABLE 1 VALUE RECOVERIES FROM SECOND-GROWTH SHORTLEAF AND LOBLOLLY PINE TREES, ARKANSAS, 1936

	Pole timber				Small sawtimber			Large sawtimber			
Diameters breast high, inches	6	8	10	12	14	16	18	20	22	24	26
A—Saw timber utilization only, per tree											
(1) Saw log volume utilized per tree, cu. ft.				15.2	23.8	33.4	46.6	63.0	80.6	98.8	118.4
(2) Saw log volume utilized per tree, bd. ft. Int. ¼ inch scale				108	158	228	325	447	582	724	873
(3) Lumber volume utilized per tree, bd. ft., mill tally				77	127	201	298	410	533	665	805
(4) Gross lumber value, f.o.b. sawmill, dollars per M ft.				24.67	23.90	22.24	23.82	24.56	25.66	26.66	27.28
(5) Gross lumber value, f.o.b. sawmill, dollars per tree				1.90	3.04	4.74	7.10	10.07	13.68	17.73	21.97
(6) Logging costs,[1] (felling, bucking, skidding, loading, truck haul, and rail transportation) dollars per tree				.52	.67	.86	1.09	1.31	1.52	1.72	1.94
(7) Saw-milling costs,[1] dollars per tree				1.27	1.96	2.93	4.14	5.48	6.89	8.40	9.90
(8) Total costs,[1] dollars per tree				1.79	2.63	3.79	5.23	6.79	8.41	10.12	11.84
(9) Net conversion value, dollars per tree (values in line 5 less costs in line 8)				.11	.41	.95	1.87	3.28	5.27	7.61	10.13
(10) Stumpage value, dollars per tree				**.055**	**.205**	**.475**	**.935**	**1.640**	**2.635**	**3.805**	**5.065**
B—Pulpwood utilization only, per tree											
(11) Pulpwood (solid wood) volume utilized per tree, cu. ft.	3.1	7.8	14.1	22.4	32.1	43.2	55.1	69.7	86.4	103.2	119.2
(12) Gross value, f.o.b. pulpmill, dollars per tree[3]	.124	.312	.564	.896	1.284	1.728	2.204	2.788	3.456	4.128	4.768
(13) Utilization costs[2] (felling, bucking, limbing, loading, unloading, and 12-mile truck haul to plant) dollars per tree	.087	.184	.299	.468	.684	.968	1.278	1.680	2.074	2.476	2.860
(14) Net conversion values, dollars per tree (values in line 12 less costs in line 13)	.037	.128	.265	.428	.600	.760	.926	1.108	1.382	1.654	1.908
(15) Stumpage value per tree	**.018**	**.064**	**.133**	**.214**	**.300**	**.380**	**.463**	**.554**	**.691**	**.827**	**.954**
C—Integrated utilization pulpwood and saw-timber, per tree											
(16) Net conversion values (pulpwood from trees 6-14 inches d.b.h., lumber only from tree above 14 inches) dollars per tree	.037	.128	.265	.428	.600	.950	1.870	3.280	5.270	7.610	10.130
(17) Net value of pulpwood from tops of saw-timber trees, dollars per tree							.176	.107	.089	.070	.013
(18) Total net value, dollars per tree	.037	.128	.265	.428	.600	.950	2.046	3.387	5.359	7.680	10.143
(19) Stumpage value, dollars per tree	**.018**	**.064**	**.133**	**.214**	**.300**	**.475**	**1.023**	**1.694**	**2.679**	**3.840**	**5.071**

[1]Wages entering into costs 25-40 cents per hour. [2]Wages entering into costs 8-15 cents per hour. [3]On basis of $4.00 per 100 cu. ft. of solid wood.

wages equal to those mentioned for logging and saw milling, so far as relative efficiency of the different classes of workers justifies.

Because the total output of goods and services determines standards of living for the Nation as a whole, and very closely determines the purchasing power and the real wages of manual labor and other personnel engaged in production, there are few problems of economics more fundamental than man-hour productivity in industry. In the southern study under consideration, it was found that time requirements for logging (felling, bucking, skidding, and hauling) varied from 2.69 man-hours per M ft. International Scale for 26-inch trees to 6.51 man-hours for 12-inch trees. In cutting pulpwood the variation in output time per 100 cu. ft. solid wood was from 5.31 man-hours for 4-inch trees to 2.09 man-hours for 12-inch trees; larger trees required more man-hours, owing to the necessity of splitting.

If sound foundations are to be laid for high wage levels in the forest industries, the type of management must be employed which produces timber of such character—from the foregoing, clearly that of relatively large size—as permits high productivity of the labor engaged. Fortunately this type of management coincides with the type needed for the good of the forest owner and of forest industry in general.

Turning now to the correlation of management, industrial, and social aspects with silvicultural measures, it should be stated that developments are too recent to have permitted many long-time tests in the forest. Ten-year plots of the Lake States Forest Experiment Station show that, in virgin northern hardwoods, light cuttings are to be urged, although cuttings up to two-thirds of the stand may be made without serious loss of growth on the merchantable trees left. With light cuttings (about one-third of the stand volume) the annual growth, mostly on large trees, amounted to 226 board feet, worth \$4.25 an acre. Stands left after a heavy cutting (about two-thirds of the stand volume) produced, partly on sapling trees, 188 board feet, worth \$2.67. With very heavy cuttings (90 per cent of stand) the growth was only on saplings and was worth only 68 cents an acre.

Similar analyses of the volume and value of growth, but without field tests over a period of years, have been made for ponderosa pine, Douglas fir, southern pine, and other species. Field tests are being made with northeastern hardwoods, ponderosa pine, Douglas fir, redwood, southern pine, and others. It becomes daily more evident that retention of thrifty large trees in the growing stock keeps a substantial percentage of the annual volume growth on high-quality merchantable stems. The continuing basis for industry is thus immediately established. Wherever this vitally important principle is applied, the long trek of the American forest industry in search of raw materials ends in its own backyard.

THE RETURN OF FOREST LAND TO PUBLIC OWNERSHIP

By W. N. SPARHAWK[1]

IN THE studies of tax delinquency among forest landowners, in progress in several parts of the United States under the authorization of the McSweeney-McNary Forest Research Act, the chief fact developed has been the extent to which lands, once in public ownership and covered with some of the finest timber the world has ever known, have been stripped of their forest wealth by the private landowner and are now returning, or threaten to return, to public ownership.

In the Lake States in 1937, new public domain studies showed that 7,850,000 acres of land in the northern forest counties of Minnesota and Wisconsin either had been forfeited for taxes, or were 5 or more years delinquent and therefore subject to forfeiture. This represents 37 per cent of the taxable area. In Michigan 2,115,000 acres of forfeited land are held by the state, and 4 to 5 million acres additional are nearing the end of the 5-year redemption period. It appears likely that by 1940 the forfeited area will reach 6 or 7 million acres—33 per cent of the gross area of the forest counties of the state.

In the Gulf States from eastern Oklahoma and Texas to Florida, taxes on more than 31½ million acres, or 13.8 per cent of the gross land area, were delinquent for 3 or more years in 1934; sales and redemption have since reduced this figure by perhaps 20 per cent. In 1933 a survey of 9 Oregon and 9 Washington counties, representing 54 per cent of the area of the Douglas fir region, showed that in the Oregon counties 2,464,481 acres (43.0 per cent of the land once taxable) were delinquent for taxes of 1930 or had been forfeited to the county for their non-payment, and that the comparable figure for Washington was 1,091,452 acres (26.3 per cent).

In the Lake and Gulf States much of the land returning, or already returned, to public ownership, has been practically denuded by clear cutting and fires. In the Pacific Northwest, more than in other regions, tax delinquency has affected land that still bears virgin and second-growth timber. Of the county-owned and delinquent privately owned land in the Oregon counties previously referred to, 66.9 per cent bore conifer sawtimber (some of it virgin) and second-growth, and only 17.5 per cent was deforested land—cut-over or burned. For the Washington counties the corresponding figures were 52.2 per cent and 35.2 per cent.

There is considerable chronic tax deliquency of forest land in such other parts of the United States as Virginia, the Carolinas, and neighboring mountain states. In New England and New York relatively little land is threatened with forfeiture for taxes, but in Pennsylvania recent studies by the state forester and the state agricultural college have revealed a large acreage delinquent for several years. In southern New Jersey, where the forest was very heavily cut and burned prior to the Civil War, 40 per cent of the acreage of some townships has not appeared on the assessment roll for many decades. In California tax delinquency is not yet widespread, but the approaching end of several large logging operations threatens to precipitate widespread abandonment of forest land.

What the presence of large acreages of nonproductive land means in terms of curtailed government services, higher tax cost to local residents, and a consequent lower standard of living, is illustrated by

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the situation in a northern Minnesota county, recently studied. About 90 per cent of the county—1,048,000 acres—is cut-over pine and swamp land. The assessed valuation (approximately one-third of full value) declined from \$8,166,311 in 1920 to \$3,086,945 in 1936, a decrease of 62 per cent. Accumulated delinquent taxes amounted to 139 per cent of the assessed valuation. Outstanding debts of all units of local government amounted to 50.4 per cent of the assessed value, or \$103.65 per capita of the county population. Additional debts for bankrupt drainage districts, amounting to \$571,000, have been assumed by the state. Even with a tax rate of 17.29 per cent (in 1936), the county has been unable to meet current cost payments and has incurred new debts annually. Public personnel has been reduced, and some public services curtailed or eliminated. State aids almost equalling the funds raised locally have been necessary to provide the essential governmental services. In 1932, for example, local property-tax collections for county purposes were \$101,680, whereas state aids were \$94,138. State aids for schools amounted to 57 per cent of the total expenditure for education, which has necessarily been curtailed.

Not only does tax-delinquent land fail to contribute its share toward support of local and state government and add to the burden of taxation on property remaining in private ownership, but tax default nurtures further default, and more and more land is drawn into the widening circle of delinquency. Carried far enough, this process discourages and even renders impossible the occupation and profitable use of the remaining privately owned land in the locality. In extreme cases whole sections of counties or states may then become virtually depopulated. If any of the people remain, they constitute pauper communities which look to the state or the federal government for funds with which to carry on the ordinary functions of local government.

Lacking a definite plan for dealing with this land, the taxing authorities have usually followed a policy of opportunism; they have disposed of their claims against it in any way that would yield some income and if possible keep the land on the tax rolls. Little or no effort has been made, in many places, to analyze the causes of the delinquency or to seek out remedies. Except in a few states where positive action has been taken to establish definite public ownership, much tax delinquent land has become virtually a no-man's land, for which neither public nor private agencies have been willing to assume the responsibilities that go with ownership.

Certain conclusions are inescapably drawn from the public-domain studies so far made. One is that in the future the prodigal son must never be allowed to leave home. Forest land now in public ownership should be retained in such ownership and administered in the public interest. Attempts to dispose of denuded land through sale to private owners, no matter how favorable the terms of sale, have usually resulted in the return of the land to the public through repeated tax default. If the land bears any standing timber there is all the more reason for the public to retain title, because it has more to lose should the timber be depleted while temporarily in private ownership. Even at considerable cost, the public should do whatever is necessary to rehabilitate the new public domain and make it eventually contribute to the support of the public household.

All evidence drawn from studies of the new public domain points to the wisdom of preventing by every possible means the reckless depletion of the forest resource where the land has already passed into private hands. Public aid, plus a *quid pro quo* of public regulation, appears necessary if the public is to avoid the squandering of what is after all its common inheritance.

FOREST STATISTICS IN ECONOMICS RESEARCH

By H. B. Steer[1]

Economic research may be regarded from two different points of view. First, it may deal with the effect of human actions on human welfare in an abstract manner, developing theories or economic laws which have no practical basis and are inapplicable to everyday activities. According to the other point of view, economic research is regarded as justifiable only to the extent that it develops practical procedures which will improve and broaden man's economic life. The practical research economist works with conditions as he finds them, bases his conclusions on fact, and is convinced of the practicability of the measures which he proposes. Aside from his training in economics, he must have an intimate and practical knowledge of the business field in which he is working.

Research in forest economics is of the second school and has been aimed to produce results that are susceptible of immediate and practical application; for like all other departments of forest research, it must indicate the way to improved forest practices. All practical forest research must be founded on economic fact. The adoption of improved methods of forest management, particularly on private lands, will depend upon the economic soundness of the measures proposed. No forester can hope to convince a lumberman or anyone else of the wisdom of changing common methods of forest management by dissertations or conversations based on abstract theories. The all-important question, "Will it pay?" can be answered only by the results of practical research in forest economics, which in turn must deal with facts—price facts, supply facts, demand facts, production facts, distribution facts, consumption facts, and all others that are pertinent to the problems at hand—facts, be it said, that have no lingering taint of conjecture or assumption. If economic facts of this quality had been available, it is reasonable to assume that intensive forestry would have been adopted much more widely and rapidly than it has been. It is probable that it hasn't been so much foresters' ignorance of economics that has made it difficult for them to get together with lumbermen, as it has been foresters' knowing so many economic "facts" that weren't so.

Economic facts seldom come easily. They are apt to be as elusive as a youthful waistline at fifty. Statistics that are in reality facts can be obtained only by unremitting and painstaking labor, by independent research, by collaboration and cooperation with other interested agencies, and by never losing sight of the maxim that "eternal vigilance is the price of accuracy."

The alpha of forest economics is costs. The omega is returns. Between the two are many related and vitally important economic factors which constitute individual research fields and yet in the last analysis affect either the cost of forestry or the returns that flow from a forest enterprise—measured not only in dollars and cents, but also in terms of many intangibles of human satisfaction and enjoyment and social welfare that cannot always be given a money value. Methods of taxation, insurance, logging and milling, production and distribution, and policies of land ownership and management, are important as subjects of research activity in direct ratio to their effect on either the costs of or the returns from scientific forestry. All of these investiga-

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tions start with the consideration of facts of supply, production, price, distribution, and consumption of forest products.

Activities of the Forest Service in gathering the multitude of forest-products statistics have been designed to furnish the facts needed in formulating policies for acquisition and management of forest land as well as for utilization of forest products.

Early statistical studies furnished much of the basic data contained in the Capper report, Senate Resolution 311, *Timber Depletion, Lumber Prices, Lumber Exports, and Concentration of Timber Ownership,* published in 1920. The work of gathering forest statistics previous to 1928 may well be considered as summarized in Statistical Bulletin 21, *American Forests and Forest Products.* This publication, which has long been considered a standard reference book, presented forest statistics of the United States, including selected statistics of national forest administration; tables of lumber production by states and species; data on lumber distribution, consumption, and prices; statistics of pulpwood, wood pulp, and paper production, consumption, prices, imports, and exports; and such data on minor forest products as were available.

The McSweeney-McNary Forest Research Act made it possible to coordinate existing fact-gathering activities and bring them into sharper focus and somewhat to enlarge their scope. Cooperation with the Bureau of the Census in collecting and compiling forest product statistics, which has been in effect for more than 20 years, has been considerably strengthened during these last 10 years. For several years, the Forest Service has collected the data for the Census in the western states. This cooperation has made it possible to build up over the years consistent records of lumber production, distribution, and consumption, similar data on other forest products, and prices of lumber, logs, and standing timber. It has been of material assistance also in other intermittent projects, such as the study of lumber used in manufactures. No other agency compiles and publishes such information, which is fundamental for developing forest plans and programs of private and public enterprises.

Close contact and cooperation have also been constantly maintained in recent years with trade associations; state and federal agencies, such as the Bureau of Foreign and Domestic Commerce and the Tariff Commission; and with the Dominion (of Canada) Bureau of Statistics; all to the end that the Forest Service may have at all times the best and most complete data that are available.

The statistics so compiled and collected have at different times been prepared and distributed in mimeographed or other temporary form. Notable among these publications is *Lumber Production, 1869-1934,* together with annual supplements issued subsequently, which presents all statistics of lumber production of record under one cover and obviates the necessity of referring to a score or more of old Census and Forest Service publications, many of which are out of print.

Publications of a more permanent nature have appeared recently or are now in process of preparation. Special attention has been given to work in the price field during the past 10 years. A bulletin on stumpage and log prices has been published for each year subsequent to 1927, the compilation of the data being so standardized that comparisons between the several years may readily be made. Similar data for 1923-27 were issued in mimeographed form. On the basis of these data a comprehensive review of stumpage prices, the first ever to be attempted, has been prepared and is now in process of publication under the title *Stumpage Prices of Privately Owned Timber in the United States.* Among its several features of special interest, this report brings together for analysis and interpretation all

of the available information on prices paid for privately owned timber in this country from the earliest date of reliable record up to and including 1934. It is based on a volume of sales well in excess of 500 billion feet. Prices of standing timber, logs, and lumber have been compared with those of other commodities, particularly farm products, with a view to determining the relative stability of prices. Data developed by this investigation clearly indicate that although stumpage, log, and lumber prices have fluctuated with economic conditions, they have been more stable than prices of other commodities, particularly farm products and raw materials.

The Forest Service has constant need for adequate and representative data on lumber prices in connection with acquisition programs and in timber management and research. Sources of reliable information are limited and adequate data are difficult to obtain. An excellent start, however, was made in 1937 through the cooperation of the Southern Hardwood Producers Association in what is probably the most complicated field of lumber prices, the southern hardwoods. F.o.b. mill prices were compiled by species, grade, and geographical region for the four quarters of 1937 and summarized for the year. As a sound basis upon which appraisals can be made, the value and usefulness of these data cannot be overemphasized. Similar data for pine in the deep South are now being compiled and it is planned to undertake like compilations for Appalachian hardwoods. When a sufficient number of years has been covered, the figures will be analyzed, a series of index numbers prepared, and trends evolved. In view of the need for this material, the lumber price project should and probably will be extended to other important regions as soon as sources of reliable data can be located and the necessary funds obtained.

Other publications in preparation that present the results of the work of fact gathering during the past 10 years are a series of regional bulletins giving for past years of record the available statistics on areas and stands of timber, production, distribution, consumption, and prices of the principal forest products. These present information not before published or readily available and serve to bring up to date much of the information appearing in Statistical Bulletin 21. There is also in preparation a report on lumber distribution and consumption in the United States for 1936, representing a compilation that is made biennially for all states and lumber production regions.

Statistics of the extent of the farm-forest resource and of the production and consumption of forest products on farms have heretofore been fragmentary and unreliable. Such data are needed in formulating programs of both forest and agricultural land use. A survey of farm-forest products has recently been undertaken in cooperation with the Bureau of Agricultural Economics under an allotment of Bankhead-Jones research funds. The findings should indicate the social significance of the farm forest resource with much greater accuracy than previous information has attained, and should be of great value to land and forest economists.

Fundamental data obtained by statistical workers are not readily publicised and consequently their work is not well known. Laboring behind the scenes, they furnish the basic data which form the foundation of all administrative plans and policies of forest management; which are indispensable as a basis for determining policies of foreign trade in forest products, and for timber and forest land appraisals; and upon which such reports as the Copeland, Hale, and Norris must be built. Such demands lend a continuing and continually increasing importance to the task of fact gathering.

THE RISE OF REALISM IN FOREST TAXATION

By R. CLIFFORD HALL[1]

NO branch of forest economics has been more shrouded in myth and mystery than forest taxation. In such an atmosphere weird theories have flourished without benefit of scientific analysis. It has been difficult to resist the delusion that if only we were clever enough we could eliminate taxation toothaches by some simple process of painless extraction. The hope dies hard of a tax panacea that will bring about the practice of forestry overnight.

The first official recognition of an American forest tax problem, so far as known, was by Governor Oliver Wolcott, Jr., of Connecticut in 1819. He approached the subject from the sound viewpoint of adjusting the tax system to take account of the income characteristics of existing forest properties. But Wolcott was far ahead of his time, and the first type of special forest tax legislation that actually came to fruition was quite different from that which he had contemplated. It was intended to encourage, not better management of existing forests, but planting of forests on treeless or denuded areas. Beginning in the West with Nebraska Territory in 1861 and in the East with Maine in 1872, a wave of tax exemptions in favor of forest planting swept the country. Supplementary or alternative enactments providing for either bounties, prizes, or rebates to reward the tree planter also became popular at this period. The few laws of this kind that were successful in accomplishing their objectives were so expensive that they had to be repealed. Some of the driftwood from this movement rests undisturbed and unused in legislative codes and compilations to this day. Now and then new attempts are made to legislate into use these outmoded methods.

The idea of tax adjustments applicable to existing forest properties rather than to planted stands was again given publicity about 1890 by J. J. Hubbell of Manistee, Michigan. Hubbell proposed exempting standing timber from the property tax and substituting a tax of 10 per cent on yield, i.e., the value of the stumpage when cut. Many others took up or evolved independently the idea of a yield tax, which eventually became current among foresters. In 1909 the report of President Theodore Roosevelt's Conservation Commission contained a monograph by Professor Fairchild of Yale University on forest taxation, in which the yield-tax idea dominated. Beginning with Michigan in 1911, more than a dozen states enacted various forms of this plan. The idea of making the plan optional with the owner and a special inducement to lure him to grow forests crept into most of this legislation. Also, Fairchild's proposals for meeting the revenue difficulties were ignored and various restrictions preventing broad application were substituted. The yield tax laws most extensively employed are those of Oregon and Louisiana, each with about half a million acres of privately owned land affected. Even here there has been practically no yield tax collected since these laws apply only to cut-over lands. So far, the yield-tax plan in practice has involved practically no payment of yield taxes—it has been Hamlet with Hamlet left out.

In 1923, when the Senate Select Committee on Reforestation was considering the taxation aspect of private forestry, it was evident that legislative experimenta-

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tion by the states had brought forth no solution of the forest tax problem. The need was clear for a more realistic approach based on a comprehensive study of the subject. The committee recommended such a study and the Congress authorized it in the Clarke-McNary Law of 1924. This study was conducted in close coordination with the forest research program provided for a few years later in the McSweeney-McNary Act.

The results of this comprehensive study were published in 1935; in a full detailed report for the student and investigator,[2] and for the general reader in a brief summary.[3] It is not necessary to review here the conclusions. It does seem worth while, however, to ask what this study has done to help the situation and to consider what remains to be accomplished.

First, the negative results may be mentioned. The idea of a simple forest tax panacea, or even of a model law that will fill the need in any and every state, ought to be dead. Anyone who examines the findings of this study can hardly fail to be convinced that no single and simple solution is possible.

The faith of foresters in the efficacy of the yield tax ought to be shaken. For those who had freely predicted that this comprehensive study would merely bolster up the yield-tax idea, its final conclusions on this subject were doubtless a surprise. If the pertinent experience and theory set forth in the report are carefully weighed, the yield tax plan can no longer be regarded as the sovereign and simple remedy it had seemed to most foresters in the past. Naturally, there are those who still cling to this idea, under the influence of doctrines no longer held by the men whose prestige gave those doctrines their original impetus.

While analysis of fallacious theories and discarding of methods shown by experience to be of little or no benefit are necessary and important steps, it is of greater interest to consider more positive results. The most fundamental accomplishment of the taxation study is an appraisal of the effects of property taxation on forest management. The gravity of these effects under certain circumstances has been demonstrated. On the other hand, widespread exaggerations of the influence of taxation under other conditions have been deflated. The favorable reaction on the tax situation of better forestry through increasing the tax base and reducing or eliminating deferment of income from forest properties has been made clear. No small part of this contribution has been the development of correct mathematical methods for evaluating the effect of the property tax on prospective financial results of forestry. The formulas developed for use in cases where the conventional methods based on estimated constant averages are unrealistic will be more widely used when more generally understood. Such useful tools will not be allowed to gather much rust.

The analysis of the effects of the property tax on forest management led directly to the broad outline of a remedial program. This analysis revealed that the tax obstacle to forestry is the result of (1) revenue requirements which are unnecessarily high because of uneconomic land settlement policies and faulty organization and functioning of local government in forest districts; (2) inefficient and haphazard administration of the tax system; and (3) that very lack of correspondence between the regular annual tax bill and the irregular receipt of income from forestry to which Governor Wolcott called attention so long ago. The causes of the tax obstacle are thus seen to be complex,

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[2]Fairchild, F. R. and Associates, Forest taxation in the United States. U. S. Dept. Agric. Misc. Pub. 218. 681 pp., Wash., D. C., Oct., 1935.

[3]Hall, R C. The forest tax problem and its solution summarized. U. S. Dept. Agric. Circ. 358. 17 pp., Wash., D. C., May, 1935.

and the remedies to be effective in the long run must go to these causes. Many of these remedies touch the whole field of local government and taxation; others relate to the peculiar problem of adjusting the property tax, so far as this may be feasible, to the flow of income from forest property. It thus becomes clear that real and lasting improvements are possible only as a part of fundamental reforms in local government and more particularly in the operation of the property tax. Better management of forests will facilitate such improvements and, as indicated before, will mitigate taxation difficulties.

The remedies which have been suggested differ from the old idea of a standard law in much the same way as the remedies now at the disposal of modern medical science differ from the "shot-gun prescription" of the family physician of yesterday. Now the remedy may be accurately fitted to the patient and to his condition at the time it is to be applied. Both the forest and tax conditions of each individual state must be considered in formulating effective forest tax measures. In many states fundamental improvements in property taxation practices are of more immediate importance than special forest tax legislation. Furthermore, political realities must be faced when framing legislation. Compromises with the ideal legislative program are usually necessary to realize progress. Willingness to make such compromises should not be confused, however, with acceptance of measures with a forestry label that are wholly unsound or unfair to the general public. Undiscriminating compromise would lead to retrogression rather than to progress. It is equally true that it would be idle to suggest holding back until a state is ready to adopt in its entirety some model plan.

The comprehensive study, in analyzing the effects of taxation on forest management, considered also other common forms of taxation—more particularly income taxes and death taxes. Since then, however, rates of death taxes have been sharply increased in this country, giving more significance to the possibility that they may become dangerous to forestry by interrupting continuity of management. In view of the changed situation, there may now be need for further study of these taxes with a view to developing more far-reaching protective measures than those which have been proposed.

To expect immediate and complete acceptance of the more novel proposals growing out of forest taxation studies is to disregard all experience with the democratic method of government. The National Tax Association, many years ago, published a model system of state and local taxation. No state has ever adopted it. Perhaps no state ever will. Its usefulness as an ideal and standard of comparison, its influence for progress, are nevertheless unquestioned. Many states, in amending their tax laws, have sought to bring them more nearly into conformity with that ideal. The specific remedies proposed as a result of the comprehensive study of forest taxation must be regarded in somewhat the same light. If only some of these measures are adopted, or if they only point the way to better practices, their purpose will have been served.

Expectation of early and spectacular results is, of course, certain to be disappointed. Many interests are involved in taxation changes and the public, not so well informed in public finance as would be desirable, distrusts change. Therefore progress is likely to be slow. But since the tax system as now administered is under many circumstances a real obstacle to forestry, the effort is worth the making. It is the function of taxation studies to guide this effort by formulating methods that recognize the realities of the different state and local situations encountered.

RESEARCH POINTS THE WAY IN FOREST INSECT CONTROL

By F. C. CRAIGHEAD[1]

LOSSES to forests and forest products from the attack of insects exceed $100,000,000 annually. Systematic surveys over a period of years indicate that more than five billion feet of mature timber has been killed annually in our western forests. Federal recognition of the importance of forest insects and of the need for organized investigations into the causes of widespread outbreaks, such as the killing of ponderosa pine by bark beetles in the Black Hills National Forest from 1895-1905, was first conceded in 1902 with a small appropriation to the Bureau of Entomology. This marked the beginning of a quarter-century of investigative effort which, by 1928, had accumulated an impressive amount of information concerning the host of insect species which injure or destroy American trees and wood, and had suggested methods for the control of many of them.

In the past decade, the thorough testing of this technical knowledge and the devising of new and improved control methods have saved many millions of dollars in control funds and a vastly greater sum in timber and in forest products exposed to insect ravages. Never before have the managers of forest lands, public and private—the Forest Service, the National Park Service, the Office of Indian Affairs, the state forestry departments, and private timber protective associations—protected the great forest resource against its insect enemies so successfully or on so wide a scale as in 1928-38. During that period federal appropriations for research on forest insects increased from $75,000 to $253,000. Of late, advice on the needs of control has been furnished by the Bureau of Entomology and Plant Quarantine on some 750,000 acres of forest land annually. The principal developments of the past decade are here briefly described.

First may be noted the improvements achieved in improved bark beetle control technique. Control of those tiny destroyers of standing timber, bark beetles, is admittedly expensive. It involves the spotting of infested trees in the forest, followed by felling, barking, and often burning of the bark to destroy the beetles and thus prevent new broods from emerging from infested trees and attacking nearby green trees. Usually the largest trees in the forest are attacked and the labor required for spotting, felling, barking and burning costs from $2 to $20 per tree, depending on its size, accessibility, type of timber and other factors. Such costs are a limiting factor in the application of control as frequently the expenditures run too high to make control economically feasible. Of recent years several new methods have greatly reduced these costs. The so-called "sun-curing method" has been tested out on a large scale in lodgepole areas in Oregon and found to be successful under certain conditions. Costs in these lodgepole types have been reduced from $1.75 or $2 to 40c or 50c per tree, where this method is applicable.

In other areas a technique for spraying oil on standing lodgepole pines and then burning the bark and broods beneath, was developed and tested on a large scale in the Rocky Mountain region. This reduced former costs by 30 to 50 per cent.

It has long been desirable to have a method of treating infested trees through the summer period that would be quick in action and avoid the use of fire, which is dangerous at that time of year. After

[1]Office of Forest Insect Investigations. U. S. Bureau of Entomology and Plant Quarantine.

considerable experimentation in California several penetrating chemical sprays were finally developed which very effectively met this need. The most promising chemicals are orthodichlorobenzene and naphthalene dissolved in light mineral fuel oils. This method is particularly well suited to the control of the mountain pine beetle broods under the thin bark of lodgepole pine in the Northern Rocky Mountain regions.

Another method which has been tested to some extent and offers considerable promise, consists in the injection of certain chemicals, such as zinc chloride and copper sulphate, into the sapstream of the infested tree, thereby poisoning the bark beetle broods. At the same time the wood is preserved for a number of years, making future salvage of these trees possible. This method has been found applicable to white pine in the northern Rocky Mountain region. On the basis of present data, it will cut the cost of previous methods by one-half or two-thirds.

One of the disadvantages of bark beetle control has been the loss of the lumber from the tree which is treated. Usually the cost of control is greater than the actual lumber value of that particular tree and benefits of the control work must come through the saving of timber values in other unattacked trees on nearby areas through prevention of the spread of the infestation. For this reason a great deal of attention has been devoted by our entomologists in the last few years to the use of so-called salvage methods of control and the Forest Service and private timberland owners have cooperated heartily. In the ponderosa pine types of eastern Oregon and eastern California, when the terrain permits caterpillar logging, prompt spotting and salvage of these trees is feasible. In other types, particularly in the Rocky Mountain regions, a number of incipient outbreaks have been controlled through local use of the infested tree before the outbreaks developed into serious proportions.

Introduction of chemicals into the sapstream of living trees for the control of insects, already mentioned, has been studied chiefly at Asheville, North Carolina. Modifications of this treatment have been applied to the eradication of the Dutch elm disease, which is carried from tree to tree by certain insects. It has been possible to cut by more than half the costs of clear-cutting certain elm areas. The trees treated by this method will not sprout and are not subsequently attacked by insects, thus doing away with the necessity of costly and difficult stump treatment, and the barking or utilization of the elm wood to prevent insects from breeding in it.

However, the most practical result of the experimental work seems to be in its application for the prevention of insect attack and decay to crude forest products, such as poles, posts, and timbers in contact with the ground and material to be used as rustic work, such as furniture, and cabins. Thus it enables the farmers, particularly in the South, to utilize pines and non-durable woods with enormous benefit. It will not compete in any sense with the commercial treatment of cross-ties or poles with creosote. For the farmer and woodlot owner, the technique consists, in the case of small trees, of simply cutting the tree off at the base and standing it in a container filled with zinc chloride or copper sulphate solution or, in the case of larger trees, of introducing the preservative solution by means of a groove sawn around the base of the tree and a flexible collar attached just under this groove to hold the solution. Only a few hours are required for the treatment but the trees should stand for about a week before the top and foliage are removed. Another simple method for larger trees is to fell them, remove the bark for a few inches at the butt and stretch over this peeled end a piece of innertube to form a con-

tainer or cup into which the chemical is poured. Tests were made in treating poles—trees with the tops removed—but the distribution of the chemicals was uneven and unsatisfactory.

In the development of the silvicultural control of insects during the past decade, our cooperative contacts with the forest experiment stations have been increased to the mutual advantage of both organizations. It is obvious that in growing future timber crops the adoption of methods that will avoid insect losses have tremendous advantage over artificial control methods which must be applied after the damage has started. Through the combined efforts of entomologists and foresters, simple silvicultural practices have been devised for the prevention of the white pine weevil damage in the New England region. By restricting plantings of pure white pine to better sites and by the group-wise development of pine and hardwoods where the site permits, serious weevil damage can be effectively prevented. Also by judicious pruning and girdling of wolf trees, stands already badly damaged can be made to produce a reasonably profitable crop. These results have greatly changed the unfavorable prospect of a few years ago for the growing of this valuable tree.

Detailed studies of the habits of the western pine beetle have greatly increased our knowledge as to the ecological and silvicultural relationships of this important enemy of ponderosa pine in northeastern California and eastern Oregon forests. The selectivity which this bark beetle exhibits for trees of certain characteristics has had an important bearing upon forest management practices in this timber type and in revising marking rules. A tree classification devised for the purpose of determining classes of susceptible pines has been of great help in this connection and has been widely adopted by foresters for marking and timber management purposes.

Spraying from the air has been developed to overcome a serious type of insect damage occurring in both conifer and hardwood forests, caused by certain larvae of moths and sawflies consuming the foliage. These defoliator outbreaks are notoriously difficult to control in the forest. In fact, the cost of applying arsenicals has in the past been prohibitive, unless the timber to be protected is to be logged within a few years. Airplane spraying and dusting have been tried, but high-speed planes flying above the tree tops are difficult to control and have not proved entirely practical. Within the last few years private concerns have applied the autogiro to this type of work. The great advantages of this slow-moving machine were immediately recognized and several experimental jobs have been contracted for and carried out over rough terrain with remarkably good results. Costs appear to be much less than by ground methods.

Considerable effort is being directed to the development of a concentrated spray mixture for application from the autogiro, and several effective formulae combining arsenicals, oils, and water have been developed. The ratio of water in these sprays is only 1 to 100 for that of the ordinary liquid sprays, thus tremendously reducing weight and consequently increasing the range of the machine and coverage of the land.

Parallel to the work done with the silviculturists, has been the cooperation of entomologists and pathologists at their several field laboratories, which has resulted in the solution of several complicated problems where insects and fungi work together to produce a combined result which neither could produce alone. It has been demonstrated that, in the case of bark beetles, the actual death of the tree results from the clogging of the water-conducting tissue in the tree by so-called "blue-stains" which these bark beetles introduce into the sapwood when they

attack. It is altogether probable that insects are entirely responsible for the spread of the Dutch elm disease.

The destruction by insects of wood in buildings, or in use as poles, cross-ties, and rustic work, constitutes something of a double loss, in that the cost of repair or replacement is usually more than the material itself. Likewise, stored lumber and rough blanks such as gun-stock supplies, pulpwood, and cordwood require special methods of protection to avoid damage.

Among the insects causing this type of injury termites are the outstanding vandals. Millions of dollars are spent annually in their control. It was determined early in the study of these insects that a few simple fundamentals in building construction will prevent these losses. These requirements, however, cannot always be applied to buildings already erected, as they often necessitate considerable remodeling which is expensive for the home owner. Commercial concerns have for some time been using so-called soil poisons for treatment of termite-infested buildings. During the past few years an extensive series of experiments have been conducted by this Bureau to test the efficacy and cost of these methods. It has already been demonstrated that soil poisons are effective for a year or two and sometimes longer and, because of their cheapness, several applications can be made when necessary. At the same time it has been found that some commercial concerns are charging for these services many times what it would cost the individual owner to buy the chemicals and apply them himself.

Although the research, examples of which have been given in the preceding paragraphs, has led to great improvements in forest insect control, and prevention of damage amounting to many times the cost of these investigations, there is still a great deal more possible. It is likely that future progress will come in the better knowledge of the inter-relation of the insects and the whole forest complex. It is not improbable that we will in the future prevent the development of serious insect outbreaks in our forests, rather than spend money in their control. In other cases, forest entomologists may satisfactorily demonstrate that insect attack is merely a symptom of unhealthy conditions in the forest requiring the correction of disturbing factors, instead of treatment of the symptoms.

A DECADE OF RESEARCH IN FOREST PATHOLOGY[1]

By CARL HARTLEY[2]

THE past decade of forest conservation in the United States has been one of vastly increased demand from forest managers and owners for information which would enable them to protect the forest against disease, and from forest industries and wood users for information to defend wood against rot and similar deterioration. Foresters in charge of our millions of acres of public forests have for the first time had at their disposal, through the Civilian Conservation Corps, the Works Progress Administration, and other new agencies, the man-power by

[1]The McSweeney-McNary Act did not cover shade-tree diseases or recently introduced diseases, hence this article does not touch on the Dutch elm disease. Space limitation prevents mention of many important subjects of study under the Act.

[2]Division of Forest Pathology, Bureau of Plant Industry, Washington, D. C.

which to combat rust, wilt, canker, rot, and others of the numerous diseases which beset the living tree. They have been joined by those working to safeguard the still greater area of private forests in an insistent demand for information on disease control. Also, in an era of particularly severe competition among raw materials for our depressed manufacturing industries, lumbermen as never before have sought technical aid to protect their product against mold, stain, and rot.

Forest tree diseases have received little attention from the state agricultural experiment stations; and they became a definitely recognized subject of study in the Department of Agriculture only in 1907, and then on a very small scale. In 1928 the McSweeney-McNary Forest Research Act authorized an ultimate $250,000 for pathology. At that time the available funds for study of native and naturalized diseases of forests and forest products totalled about 46 per cent of that amount, of which about half were earmarked for chestnut blight and blister rust. Since passage of the Act the available funds for this work have increased to about 55 per cent of the amount set by the authorization.

Seedling Diseases

Diseases attack trees from the moment of their emergence from the parent seed. Earlier studies in forest nurseries had been sufficient to provide fairly satisfactory preventive methods for all of the disease conditions that were serious in the small number of nurseries then existing. The expansion in forest planting for both timber production and soil conservation during the last half of the decade multiplied many times the area of forest nurseries and the number of species grown, particularly hardwoods, with consequent multiplication of the number of problems. It was found that the seedbed treatments formerly employed had affected only the surface soil layers and modifications of the interpretation of old results have been necessary. Two promising new chemicals for seedbed treatment have been brought into the picture. New nurseries were found to be suffering avoidable disease losses favored by overdense sowing and by their use of alkaline water, lime-bearing sand for seedbed cover, and nitrogen application in too great quantity or at the wrong time. At some of the new nurseries deficiency diseases were encountered, which have been traced in a considerable number of cases to deficiency or unbalance in nitrogen, phosphorus, or iron, and found in some cases to be associated with root-fungus abnormalities. For the earlier acidic seedbed treatments against damping off there have been substituted under some conditions crude phosphoric acid or ferrous sulphate, each of which offers the possibility of combining direct control of damping off with the supplying of one of the elements in which many soils are deficient.

Disease control in nurseries attempts not only to improve the quality and lower the cost of the planting stock but also to prevent the introduction of diseases into plantations. In the South, for example, native stem rusts of pine, formerly considered of minor significance, were found to have infected many slash and loblolly seedlings in those forest nurseries where oaks, the alternate host of the rusts, grew nearby. Steps are being taken to keep the infected stock from being used in field plantings and to protect subsequent seedling crops by eradicating oak near the nurseries.

Plantation Diseases

Young natural stands and plantations on properly selected sites usually suffer less from diseases during their first few years than do nurseries. An important exception is found in the young pine stands and plantings of the Gulf States,

where fire control has aided the increase of some of the fungi. The brown-spot needle disease of longleaf pine has been shown to so weaken trees on many sites as to delay by ten years the commencement of height growth. Slash pine, the other desired species for planting on the Coastal Plain, is less promising than formerly because of the previously mentioned stem rusts. Spraying and controlled burning have been found to contribute to the control of the brown spot, and elimination of the scrub oaks to the control of rust, but these measures are of very limited practicability, and the practical problem must be considered further.

In the southern Great Plains Region the so-called Texas root-rot is a hazard to be avoided. Surveys prior to planting have located infected areas and thus reduced the danger from serious losses in federal shelterbelts.

In many plantations in the East there is reason to expect disease, at or after the time the crowns close, from parasites that ordinarily are unimportant. Both theory and the experience in other countries support the expectation of trouble. American plantations are now reaching the age in some places at which the same sort of evidence is being secured. An example is a threatening canker disease (Tympanis) in the older red pine plantations in the Northeast which has been found due to the use of the species a short distance outside of its natural range or on poorly adapted sites. Such diseases can sometimes be controlled or decreased by opportune thinning, but the results of the studies thus far made indicate that to insure healthy stands much greater care is needed in the selection of species and seed sources before the planting is made.

Diseases in Forests

Studies of native diseases in the forest had formerly been directed mainly toward control of the heart rots of stands of seedling origin and merchantable age. In the past decade the relation of fire wounds to butt rot of hardwoods has been further studied. The timber stand improvement activities made possible by C.C.C. labor have created unprecedented opportunities for decreasing disease hazards in young stands, and raised numerous questions as to procedure on which there was little previous information. Butt rot of sprout hardwoods has been recognized as a major problem in the central and northern states. Oak sprouts are found to be fairly safe from infection through the old stump if the stump is small or if the sprout originated low on the stump. Attention to sprout origin and height of union makes it possible to select crop trees with low decay hazard, and to thin sprout clumps with minimum danger of admitting decay.

Recent studies of western red rot in the Black Hills of South Dakota show that the amount of rot in future ponderosa pine saw timber can be reduced if stands can be kept quite dense until they are at least 70 years old. Even better protection can be afforded by pruning and thinning operations which can be modified to discriminate against decay without jeopardizing silvicultural objectives.

In the Northeast special sanitation operations against Nectria cankers on many hardwood species have been found impracticable. Studies of canker incidence as related to site quality have resulted in recommendation to develop softwood mixtures where the hardwoods are excessively cankered, and elsewhere, when selecting crop trees, merely to avoid those with incipient cankers.

Basic studies, without which consistent progress in forest pathology cannot be made, have been continued. They have covered the dwarf mistletoes of the conifers, which are among the most serious of the growth-reducing factors in the Southwest; the relation between bark bee-

les and the fungi parasitic in sap wood; and the causal organisms of hardwood cankers and heart rots. The first virus disease of a temperate-zone timber tree has been demonstrated, on black locust.

Naturalized Diseases

The rapid development of white pine blister rust in the valuable and highly susceptible species of the Northwest and the Pacific coast had resulted in the extension to those territories of the studies that had previously been made on this disease in the East. A method has been developed for determining age of infections on pine. Information with practical bearing has been obtained on the relative infection hazard from the numerous western species of Ribes, the distance of spread of infection from Ribes to pine, and the damage to be anticipated to pine of different ages and in the presence of different amounts of Ribes.

In connection with the last stages of the extermination of the chestnut by blight, continued studies of apparently resistant native trees have failed to locate any that promise reestablishment of the species. A pathologist therefore went to Asia to secure the best strains of blight-resistant chestnuts in the native home of the disease. The seedlings from the imported nuts were sent for trial to the government and state foresters, to tannin-extract plants, and to private planters. Unfortunately most of the early plantings were made in open fields and abandoned agricultural land, where they failed. Where the seedlings had real forest soil conditions without too much overhead shade, they grew rapidly and resisted the attacks of the blight and other fungus diseases. It is too early to predict the future of these Asiatic chestnuts, but some of them look promising. As most of them do not have the straightness and height of the American chestnut, they have been crossed with the American, and the resultant hybrids are being tested for resistance, rate of growth, and other qualities.

Decay of Logging Slash

Because of the need for cheap disposal of slash left in logging, in a way that will hasten decay and thus reduce the length of time that it is a fire hazard, studies were continued on the factors controlling slash decay. Previous work in the Southwest and Northeast was extended to some other parts of the country. In general, it has been found that some of the cheaper methods are quite as effective in hastening decay as the more expensive ones, but that the rate of decay and choice of method of disposal depend on site and exposure.

Deterioration of Killed Timber

As an aid in salvaging wind-thrown, fire-killed, and insect-killed conifers, their rate of deterioration was studied in cooperation with the Bureau of Entomology and Plant Quarantine. Some species were found to possess heartwood worth salvage many years after their death. Similar studies were made on the vast stands of blight-killed chestnut in the southern Appalachians. It was shown that trees can be utilized for tannin manufacture for 20 or more years after death. This fact is of very great importance, because chestnut is the source of over half of the vegetable tanning produced for leather manufacture in this country, and no satisfactory domestic substitute has been found.

Deterioration of Forest Products

Prior to 1930 pine and hardwood manufacturers, particularly in the Gulf States and the lower Mississippi Valley, were suffering serious losses in lumber from degrade because of sap-staining and molding fungi, which prejudiced consumers against wood. Since then the knowledge of the causal organisms and their dissemination has been materially advanced

and the effect of some of them on strength of the wood has been determined. With the cooperation and financial assistance of southern lumbermen and chemical companies, the stain-preventive qualities of more than 200 chemicals or combinations of chemicals have been explored. Inexpensive dipping treatments effective for both pine and hardwoods and practicable at both large and small mills have been developed. Their general adoption by southern mills and extension of their use to the western and Lakes states resulted in the treatment of approximately 4 billion feet of lumber last year. Treatments for logs delayed in handling have been obtained which appear effective during the parts of the year when beetles are inactive.

Studies of the decay problem have been less active than those in the field of sapstain. In the fundamental phase there has been increase in knowledge of chemistry of decay, of the oxygen requirements of decay fungi, and of the effect of steam or other heat treatment on the fungus resistance of wood, the last also having direct practical bearing. The dipping of lumber at the saw mills to control sapstain, and the increased interest in improved handling practices that has been connected with it, have unquestionably resulted also in some decrease in the amount of incipient decay infection in stored lumber, and have thus tended to increase the general quality and usefulness of wood that goes into construction.

Status and Prospects

The principal advances of the decade have been in the direction of immediate application, under the strong stimuli in that direction that have come from the demands of the lumbermen for methods of controlling sap stain and from the C.C.C. in the prevention of seedling and forest disease losses. There has been a decided increase in the general knowledge of diseases, particularly in the oaks and northern hardwoods. The increases in fundamental knowledge have scarcely, however, kept pace with the applied research, the incompleteness of our basic knowledge being well illustrated by the fact that in spite of the wide distribution of viruses among living things, but a single virus disease is known on an American timber species. In general, the progress during the decade, if viewed by itself, has been considerable; but by comparison with the number of tree species and diseases to be covered and the complexity of the conditions affecting their control, the accomplishments thus far have to be regarded as very inadequate.

Hopeful indications for the future are found in the fact that the number of foresters acquainted with diseases and making intelligent observations and control efforts against them is much greater than ever before; and that the plant pathologists of state and endowed institutions have been stimulated to the point of taking some active part in forest disease research, and industry to an active part in the study of the fungus defects of forest products. Among the subjects which seem in the light of the past decade to deserve more emphasis in the next are plantation diseases, the association of pseudomycorrhizae with poor growth, the pathology of wood parenchyma, and the reduction of the decay hazard in buildings.

FOREST-WILDLIFE RELATIONSHIP: WHAT HAS BEEN ACCOMPLISHED THROUGH RESEARCH

By LEO K. COUCH[1]

FORESTERS and range-land administrators have long been concerned over the animal factor in forest tree reproduction by natural and artificial means and the effect of wildlife on the vegetative composition, production, and disturbances of desirable and normal plant succession. They have felt the need for adjusting forestry practices to benefit the desirable wildlife species that have their habitats on the range and in the forest.

To supply this need for determining the intricate biotic relationships, the Biological Survey, in cooperation with the Forest Service, established field biologists at the different forest and range experiment stations under the terms of the McSweeney-McNary Forest Research Act. A program was laid out to determine the intensity and importance of the animal factor, to point out approved practices necessary to minimize this factor and needed control measures on harmful species, and to determine the necessary manipulation of wildlife food and cover in a forest stand to obtain desirable optimum wildlife populations. Early in the first decade of these investigations it was found that variations in forest and range types throughout the country and differences in bird and animal species made impossible the development of any standard practices, except in the immediate region surrounding the investigator. The use of fire, for example, as a tool for better forest and game production in one area, may be ruinous in a different type not far away. For these reasons the findings recorded on a few of the major projects are listed according to Forest Service research centers. In so short a paper only a few of the more important findings can be recorded.

California Forest and Range Experiment Station

Three years of investigations determined that white-footed mice (Peromyscus) in times of cyclic abundance are a decisive factor in limiting the natural seeding of Jeffrey, ponderosa, and sugar pines. Cut-over or burned over areas in northern California, in place of pine, have a tendency to produce brush types and such small-seeded tree species as hemlock, cedar, and white fir. On areas planted to young pine seedlings, rabbits (Lepus and Sylvilagus) are responsible for much clipping and low survival.

Rodents, including ground squirrels (Citellus), pocket gophers (Thomomys), field mice (Peromyscus, Perognathus, and Microtus) have a pronounced effect, particularly in dry years, on a range production, as shown by studies at the San Joaquin Branch Station. Through exclosure and inclosure plots the contrast between normal and rodent-infested ranges under identical conditions has been shown. Where the disturbance by high rodent populations had not gone too far, removal of rodents resulted in a remarkable recovery in range-grass production and composition.

Studies are now under way to develop technique for determining seasonal rodent populations and the range-rodent pressure, and to work out predictable tables on cyclic rodent fluctuations as a practical basis for the forester's use in planning the best seasons for planting or reseeding with the minimum of loss. The predator-deer relationships and mortality factors in range-quail production are under investigation.

[1]U. S. Biological Survey.

Lake States Forest Experiment Station

Intensive studies on reforestation of cut-over lands in Minnesota indicated that the snowshoe hare (Lepus) is responsible for low planting survival in white, red, and jack pines. A study of population densities and cyclic fluctuation gave information to the forester as to the time of planting to insure a minimum of loss. Control measures were worked out by the Biological Survey's Control Methods Research Laboratory.

The problem of cedar regeneration in the Lake States, in the face of high wintering deer populations, was effectively handled experimentally by clump planting of large conifers in cut-over or burned-over areas producing good winter browse but little or no winter cover. Use of these intermittent cover "islands" indicates a possible drawing from congested winter deer yards of sufficient numbers of deer to permit cedar regeneration. Herd control by yearly hunting removal is necessary if the cedar swamps are to reproduce.

A study of the stream-side requirements for beavers, based on the yearly growth of favored vegetation necessary to feed one beaver, yielded data for beaver management and for correlation with good forestry practices. The animal factor in natural conifer reproduction and the effect of commercial cedar clipping for the florists' and decorators' trade on the availability and regrowth of winter deer foods are problems under study in the Lake States.

Pacific Northwest Forest Experiment Station

Plantations of Douglas fir have been repeatedly subject to damage by the varying hare (Lepus) in the Northwest. Deterrent sprays applied on nursery stock has helped to minimize the loss of young seedlings. Investigations of projected planting sites to predetermine rabbit populations have helped in planning planting operations. As in California, white-footed mice (Peromyscus) have been found a serious detrimental factor in Douglas fir and ponderosa pine reproduction.

In studies of two adjacent sites it was found that the natural regeneration of the Douglas fir is influenced by compulsory slash burning following logging, as in the burned areas such rodents as rabbits, mountain beavers (Aplodontia), and white-footed mice, can more easily glean the seeds and seedlings. The unburned slash area yielded a much denser second growth.

Range-rodent studies revealed that a marked increase in forage production and composition occurred after a sharp reduction in the numbers of ground squirrels (Citellus) and pocket gophers (Thomomys).

Northeast Forest Experiment Station

Studies conducted on the Pillsbury Reservation in New Hampshire yielded some definite, usable information. In investigating the effects of silvicultural practices on wildlife, it was found that adding exotic plants to the forest stand to increase the food supply was too expensive and moreover was unnecessary; that annual food patches in a New England forest were negative in results as the food was not available at the critical winter period; and that openings in the northern hardwood type of forest to be of optimum benefit to wildlife must have the minimum size of twice the height of the adjacent canopy. Other studies showed that the pruning of volunteer Malus was effective in increasing winter food supply, as was also release cuttings to favor Crataegus; and that the development of so-called game "runs" cannot be laid out arbitrarily in the forest, but should be adapted to the type of dominant plant composition and succession. Selective logging in northern hardwoods was effective for improving the area for wildlife uses, provided the cutting

was heavy. Cover in such types was increased favorably for several species by piling the slash, a practice not considered an excessive fire hazard.

Appalachian Forest Experiment Station

The role of birds and animals in mixed hardwood and softwood forests in the southern Appalachians was determined by studies of several hundred species. Observations indicated that rodent populations were low in a normal growing forest, and were only locally a factor in forest production. Rodent populations, however, had a tendency to rise rapidly following cutting operations, and the rodents together with seed-eating birds were a severe check on natural pine reproduction. In that region the piling and burning of slash removed rodent harbors and produced conditions similar to those found favorable for pine stands in old fields.

The rapid increase of deer on the Pisgah National Forest had a profound effect on plant succession, favoring the unpalatable tree and shrub species to the detriment of the more desirable forest type. Seasonal failures in the mast production of such trees as oaks and gums result in a change in the feeding habits of many wildlife species, influencing greatly the composition of mixed hardwood stands through emphasis on the remaining mast crop of other tree species.

Southern Forest Experiment Station

Studies in longleaf pine reproduction proved that rodents were almost a negligible factor. Birds in good seed years, however, almost cleaned up the seed crop. Migrant flocks of blackbirds, mourning doves, meadowlarks, and many lesser groups were attracted to longleaf pine areas for the mast. Check plots indicated that in off-seed years the birds flocked elsewhere. The problems left to solve are how much artificial reseeding can be done without attracting bird concentrations and how seed germination can be hastened to shorten the time of seed exposure. Plans are being worked out on reseeding technique least likely to attract birds.

Southwestern Forest and Range Experiment Station

The role of such rodents as jack rabbits, ground squirrels, prairie dogs, and kangaroo rats (Dipodomys) in the southwestern ranges was determined chiefly on the Santa Rita Experimental Range, Ariz., and important data on their relation to soil conservation, watershed protection, and forage maintenance were obtained. Studies show that 12.7 black-tailed jack rabbits consumed as much vegetation as one sheep, and 63.6 ate as much as one cow. Technique was developed for determining rodent populations, the dominant species, and points at which control might be justified. The rodent influence on burroweed (Isocoma), its spread, and increase was determined. The results of the investigation of the economic status, habitat, migrations, and life habits of jack rabbits, and their relation to the distribution of plants, have been published.

The relation of porcupines to timber production in the Southwest has also been studied and the findings published. The influences affecting Gambel quail and other upland-bird production have been investigated. Further studies of these range-wildlife relationships are needed.

Lines of Research Needed

The research work in forest-wildlife problems for the ten-year period has been concerned with the role of the many hundred species in their effect on forests and ranges. Future research should deal with the forest ecology, the influence of silvicultural methods and land use practice on wildlife. It is apparent that certain forest and range practices can be integrated with wildlife requirements at little sacrifice to either.

PROGRESS IN FIRE-WEATHER SERVICE DURING THE LAST DECADE

By LELAND T. PIERCE[1]

ALTHOUGH weather forecasts have been used for many years as an aid in the protection of forests from fire, the present organized program is comparatively new. The need for specialized forecasts to meet the particular needs of forest protection agencies was first brought to the attention of the Weather Bureau in 1912, largely as a result of disastrous fires which occurred in Washington and Oregon in 1910 and 1912. E. A. Beals, then district forecaster in Portland, Oregon, was urged by the Forest Service and the Western Forestry and Conservation Association to institute a program of forecasting suitable to the needs of forest protection agencies. Before the 1914 season of hazard began, arrangements had been completed to collect a small number of weather observations from forested areas, and to issue special forecasts for Oregon, Washington, California, and Idaho. This marks the begining of what is now known as the fire-weather warning service, although it was not given such official designation until 1916.

In connection with the new program it was necessary to establish meteorological stations in the forests, and for the forecaster to study the topography of the forested areas in order to make the forecasts applicable locally to relatively small areas. These studies yielded gratifying results, and the new service proved of such great value in fire protection work that the practice of issuing specialized forecasts was extended during the next few years to other states, principally west of the Mississippi River. Predictions in all sections were confined for the most part to wind, weather, and temperature conditions favorable to the inception and spread of forest fires. With increasing experience in this work, however, it soon became evident that this forecasting program, forming as it did only an incidental part of the forecaster's duties, was inadequate to meet the need and entirely disproportionate to the values at stake.

Early in 1924 it became apparent that, because of the abnormal dryness of the preceding winter season, the approaching fire season might be disastrous. The Western Forestry and Conservation Association, recognizing that insufficient funds were available to the Weather Bureau, offered financial assistance if meteorologists would be assigned exclusively to the fire-weather work in Washington and Oregon. This generous offer was accepted, and C. I. Dague and G. W. Alexander were assigned respectively to Portland and Seattle for this purpose. Apprehensions regarding the severity of the 1924 season were amply realized, and the forecasts issued were markedly successful. Thus the principle was definitely established that fire-weather forecasting is a highly specialized problem which requires the full-time attention of trained meteorologists. It was the success attained that season which induced the Western Forestry and Conservation Association through its able and energetic manager, E. T. Allen, to appeal to the President, Director of the Budget, and the Congress for appropriations which would enable the Weather Bureau to improve and expand its fire-weather warning program. They were successful, and in 1926 for the first time money was pro-

[1]U. S. Weather Bureau.

vided for a definite fire-weather unit in the Weather Bureau organization.

Seven separate fire-weather districts were established during the next two years, located as follows:

District	Headquarters
1—California	San Francisco
2—Oregon	Portland
3—Washington	Seattle
4—Montana and northern Idaho	Spokane
5—Southern Idaho	Boise
6—Minnesota, Wisconsin and Michigan	Duluth
7—New England and New York	Boston

A meteorologist was assigned in charge of each district. His duties were to establish and maintain a network of meteorological substations in the forests, to receive daily reports by telephone or telegraph, to issue forecasts and warnings as required, and to engage in research with a view toward localizing the forecasts, making them in more detail and improving their accuracy.

The same basic operating plan was followed out in each district. Officials in charge of the work, through close cooperation with forestry agencies, have gained an understanding of local problems relating to fire occurrence and control and have thereby been able to develop a forecasting program peculiarly suited to requirements in the various forests. Fire-weather forecasters have been alive to the varied and changing needs of forestry organizations, and have been alert to meet the need for additional service. As a result, minor changes have been made from time to time in the operating procedure, such as varying the time of issuing forecasts, giving more detailed information, and emphasizing expectations of those weather elements most important in the local fire problem.

In 1929, a supplementary forecasting service was inaugurated in California, based on experience of previous seasons, a recognition of the changing needs of forest protection agencies, and an appreciation of their problems gained through conference with forestry officials, close observation, and study. While observing suppression efforts on a large fire in his district, L. G. Gray, who has immediate supervision of the fire-weather work in California, saw the necessity for short-period forecasts applicable specifically to the area in which large fires are burning. Immediately he made arrangements to collect weather reports by telephone at the site of this fire, and prepared a weather map which included reports from substations in surrounding forests. Short-range forecasts were then issued, stressing those weather elements having the most important bearing on the fire. So successful were his efforts on this occasion, and so pleased were forestry officials with this demonstration of "on the ground" forecasting, that plans were soon made to provide the Weather Bureau with a truck equipped with meteorological and radio equipment which could be driven on call to large going fires and used as a mobile forecasting unit. The U. S. Forest Service and the California Division of Forestry supplied a truck specially designed for the purpose—a novelty and the first of its kind. It was equipped with a radio receiver, meteorological instruments, and all other facilities required for the collection of weather information and preparation of manuscript weather maps. A radio operator accompanied it for the purpose of copying the weather broadcasts.

This specially equipped "mobile unit" proved beyond question in the 1929 and succeeding season the practicability and value of such service in direct suppression work. By its use the forecaster becomes an integral part of the fire-fighting organization and is available for consultation in the formulation of suppression plans and for advice regarding the effects which wind, temperature, and humidity expected to occur during the next several

hours may have on the plans and tactics employed by the fire fighters. As a result of this initial success in California, plans were laid for the extension of the same intensified service to other districts in which a similar need existed. An increase in appropriations was made available during the fiscal year 1937 for this purpose, and four new trucks together with other equipment of improved design were purchased for assignment to northern California, Oregon, Washington, and Montana.

An integral part of this expanded service was the assignment of additional personnel in the western districts. Prior to 1936, a part of the regular fire-weather forecasting and other duties in connection with this project had to be carried by the district forecaster at San Francisco and by the officials in charge of stations serving as headquarters in other districts. Since these men were already fully burdened by other regular duties, this arrangement was very unsatisfactory. When the truck and its personnel were engaged on going fire duty, it was necessary for the official in charge of the station or his assistants to prepare charts, issue forecasts, and carry on the fire-weather activities in other parts of the district. Therefore provision was made for an additional forecaster to travel with and issue forecasts from the mobile unit. This allowed the meteorologist in charge of the fire-weather district to remain at the headquarters office. Owing to the latitudinal spread of the California district, two forecasters were assigned to serve respectively in northern and southern parts of the state; and one each in Washington and Oregon.

Service features of the fire-weather program have developed along with, but to a considerable extent independently of the research activities. It is expected, however, that in the continued refinement of the service, research will play an increasingly important part. No men are now assigned exclusively to research in the field of fire-weather, but opportunity exists for much research by the regular personnel during the several months of the year when little field activity is possible. Eventually, it is planned that the research program will be much strengthened by the assignment work of meteorologists and computers employed for this purpose only, and having no field-service responsibilities.

Research work and statistical studies in all districts have been directed primarily toward the solution of problems confronting the forecasters in their daily work, and for this reason the nature of studies performed has varied quite widely between districts. Essential to all fire-weather research, with resultant improvement in the accuracy of forecasts, are substation records covering a sufficient period of years to represent conditions accurately as they exist in the forests. Lack of these records has been a handicap in the past; but there are now good records covering about 10 years in all districts, eastern as well as western, a goodly portion of which have been compiled and are now in convenient form for use. Through the use of these records, attention has been given to the building up of what might be termed a "fire climatology" for the districts. Seasonal, monthly, and 10-day normals of the various weather elements are considered to be indispensable adjuncts to the practical and theoretical aspects of the problem. In the task of compiling records, C.W.A. and W.P.A. assistance has been utilized in all districts in which the period of record is sufficiently long. Numerous studies have been made of the effects of topography upon temperature, wind, humidity, etc., as an aid in the localization of forecasts. Also several serious fire situations have been analyzed in detail in various parts of the country.

In the western districts, lightning storms present the most serious single fire-weather problem and have merited the greatest amount of study. Their accurate prediction, both with respect to occurrence and fire-starting characteristics, is of incalculable importance. Though this is very difficult of accomplishment, meteorologists in all western districts are engaged in attacking this problem. Already the knowledge of thunderstorm occurrence and behavior thus acquired has been reflected to a marked degree in the increased accuracy and degree of localization of forecasts. It has been rather definitely established that thunderstorms travel in more or less well-defined and predictable paths, and that the number of fires started, as well as the forest elevations to be affected, is largely a function of the height at which the clouds form. Predictions of maximum temperatures and attendant minimum humidities have been materially improved by the development of formulae applicable to specific locations.

Fire-weather research has as its first objective the improvement of forecasts in order more completely to meet the requirements of forestry organizations for weather information. Progress toward this end is being made and will continue largely through detailed analysis of surface reports, study of given fire situations, etc. In recent years, however, increasing attention has been paid to the influence of upper-air conditions upon the occurrence of weather elements at the surface. This is a natural result of the increasing amount of winds-aloft, airplane, and radio-meteorograph observational data made available through the enlarged airways program of the Weather Bureau. For many years forecasters have been making use of this information to the extent of its availability, but with increased current knowledge of the detailed characteristics and structure of the upper atmosphere, substantially larger service benefits may be expected.

Progress in the fire-weather work is expected to be made through application of results obtained from research projects now in progress and those planned for the future. Attention of fire-weather forecasters will constantly be directed toward refinement of present methods and development of new ones.

A LOOK AHEAD

By C. L. FORSLING[1]

THE articles in this issue of the JOURNAL attest to the substantial advances made in federal forest research in recent years with a great impetus in the last ten years under the McSweeney-McNary Act. As a result, aided by the very substantial contribution made by state, endowed, private, and other agencies, forest problems in this country are being met with far more intelligence than ever before. With this degree of progress to date, it might well be asked, what is the future need for forest research? Is the end in sight or should the program be greatly enlarged?

The answer to these questions seems fairly obvious; for in spite of substantial progress along many lines we are still faced with a wilderness of unsolved problems. The fact is that research is never finished. Individual research projects if they are properly conceived and executed should definitely reach an end with results either positive or negative, but in forestry, as in other fields, specific problems serve almost invariably to bring into focus related or basic problems the solution of which may be of more far-reaching importance than the original problem. Added to these are the problems introduced by changing physical, economic, and political conditions. It seems evident that if existing and future needs are to be fulfilled, not only must full advantage be taken of the advancement in forest research in the past ten years but the present program must be enlarged substantially.

Progress in the next decade should be much greater than in the past ten years, for a number of reasons. In the first place, a great many research projects now under way will only reach fruition in the next few years. Another reason is that a considerably larger number of trained personnel is available than ten or fifteen years ago—workers who have had a decade or more to develop experience, judgment, and deep insight into problems. A large return is to be expected from this investment in training.

Progress will be stimulated also by the numerous up-to-date research facilities that have been developed. The modern Forest Products Laboratory, if adequately equipped and manned, removes many early obstacles to progress in the field of wood utilization. The establishment of over 90 experimental forests and ranges, reasonably well equipped and fairly secure from disturbance, marks a similar advantage in the solution of various field problems. Still another factor is the progress made in the related and especially the basic sciences which helps to answer many questions in forestry. Also, the inertia involved in awakening interest in and evolving a program of forest research has been overcome and it should now be easier to keep the work moving.

These advantages over ten years ago will help but will not adequately meet the situation as regards existing problems and their solution. A few examples will serve to illustrate the kind of problems in which little more than a start has as yet been made. In wood utilization, the unlocking of the secrets of lignin is only beginning to indicate uses for nearly one-third of the wood substance heretofore wasted and an obstacle in pulping and other use of the cellulose. The better understanding of its structure, its use in plastics, and in the production of useful chemical products, as the result of the recent development of a process for hydrogenating lignin, indicate but a few of the possibilities for this ma-

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terial. Opportunities appear to lie ahead also in new methods for converting wood cellulose to new uses. Further developments with both lignin and cellulose, as well as all that ingenuity can bring forth on new chemical and physical processes in distillation, in fermentation, pulping, and mechanical conversion of wood, are needed to solve the single problem in forest utilization—and there are many such problems—of how to utilize at some gain the vast bulk of small and inferior materials which must be removed from the forest stand in thinnings and stand improvement operations. In some localities, as in the Ozarks, where promiscuous cutting, burning, and grazing the woods have left an inferior growth of scrub oak which only long-time care and protection can replace, the future support of thousands of families, as well as the transformation of the scrub oak type into more productive forests for the future, depends on finding new ways of converting scrub oak into useful products.

Barely a start has been made in tree breeding to develop crosses and hybrids and select strains of trees adapted to the rapid and more profitable production of desired material, whether for chemical conversion or for the use of the wood in the natural form. Another phase of the problem the geneticist has to deal with is the development of strains of trees for adverse conditions of growth, in order that the now treeless plains and prairies may enjoy the shelter from drying winds and sweltering sun which only trees can afford. In other words, in the future a large part of the job may well be to develop the strain of tree needed for specific purposes.

Incidentally, success in introducing new varieties of many trees depends upon finding ways, through the use of hormones or by plant breeding itself, to propagate these species from cuttings or by similar vegetative means. If breeding must be carried on by fixing new qualities to the extent that they will be carried by the seed, the job becomes hopeless because of the long time required. Already, however, rooting has been induced experimentally by the use of artificial hormones, with both conifers, including pine, and hardwoods; but the method is yet to be put on a productive basis.

In both forest management and range management, research has the task ahead of carrying present practices beyond present rule-of-thumb methods and present doubt in many cases of how to get the most desirable results in timber growing in the forest or in production and utilization of forage on the range. Barely more than a start has been made in gaining an adequate understanding of the interactions of climate, soil, and vegetation and of what these involve in the regeneration, growing, and harvesting of forest crops under the wide variety of conditions in the United States. Among other possibilities, it may be found highly useful to delve much further than heretofore into plant physiology, including biochemistry and all its ramifications, to gain a better understanding of growth requirements. As the forest scientist understands more of the growth phenomenon of the plants he will be better able to discover or develop simple indicators or tests which may be used to great advantage as guides in applied forestry.

Still other fields urgently calling for more work to supplement the good starts already made are the protection of forests from fire, disease, and insects. Forest and range biology, also, hold the solution of many current pressing problems of wildlife management in relation to the use of forest and range lands.

Lack of factual data has led to sharp differences of opinion as to the value of forests in helping to control floods. This is especially true of major floods that follow protracted precipitation in winter when vegetation uses but little water in growth. It is contended by some that under these conditions the ground becomes

saturated, is no longer able to absorb moisture, and additional rainfall under such conditions, must run off and will create floods, and that this condition will occur with or without forest cover. On the other hand, it has been proved beyond reasonable doubt that unburned and undepleted forest and range plant cover is a very definite deterrent to floods, especially flash floods from torrential storms, in parts of the West. Until complete measurements and analysis of results under a variety of conditions are made, it will not be known with sufficient accuracy how much water a forest-covered area will absorb under different conditions as compared to stubble land, burned pasture land, or burned-over forest land, especially where soils are deep enough to hold a large volume of water, as is the case in extensive areas. Determining the facts basic to a reasonable comprehensive understanding of the influence of plant cover on floods, although a sizable job in itself, is but one phase of the whole problem of managing forest lands in the interest of flood control, streamflow regulation, and water yield for navigation, power, and irrigation.

Since economic and social conditions constitute a constantly shifting scene with ever-changing circumstances and influencing factors, research in forest economics, more obviously than some of the other fields, sees no end. Latest to get under way, it is still the furthest behind in the whole forest research field. The Forest Survey, less than half finished and being slowed down materially in order to make special analyses to meet current demands, is an example of how urgent is the need for economic information. An up-to-date "set of books" which will show the present status of timber supplies, present and future requirements, and what are the opportunities to meet them is essential to balancing local, regional, and national timber budgets. Current information on supplies and demand for different kinds of forest materials, on cost and returns to determine what are profitable and unprofitable procedures in timber growing and utilization, on marketing of timber products, and on the socially desirable forms of organization of forest enterprises, are a few of the many things which forest economics research needs to develop.

The report entitled "A National Program of Forest Research," published in 1936 by the American Tree Association for the Society of American Foresters, sets forth in detail the fields and problems in need of research as recognized at that time. The McSweeney-McNary Act sought to implement that program. A comparison of the program now under way with the one then proposed and written into the Act indicates that the needs as visualized at that time are being met about two-thirds at the present time. In the meantime new problems have arisen and the gap between what is being done and what ought to be done has been widened still further. The work which the various federal agencies now have under way is, on the whole, approximately only one-fourth the program necessary to meet the federal government's share of the needed program of forest research.

In conclusion it may be said that while progress has been made, forest research has not made up for the time lost in the late start, is meeting recognized problems barely more than one-fourth the way, and probably is not holding its own with respect to new problems. As compared to industrial research, agricultural research is receiving only about one-seventh of the financial support it should receive, and forestry is in the "one-third ill-fed, ill-housed, ill-clothed" of the agricultural research field. If forest research is not to remain a ragged and backward Cinderella, this situation must be altered. Cinderella was never vulgar enough to say so, but all of us surmise that Prince Charming had money.